COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

August 1955

Photo by Lewis Stackmeyer

Turbine on the Hudson; see page 41

Design and Selection of Cooling Towers — I

Engineering Problems of Power Reactors

Waste Heat Boiler in English Refinery

日本の國力増進

Tokyo's new Chiba power plant to be served by

The largest boiler ever shipped from the U. S. A.

In Japan today there's growth – of industry, of agriculture, of domestic living standards. It's a growth that requires additional electrical power in huge quantities. Throughout Japan, therefore, utility companies are expanding generating facilities at an unprecedented rate.

Part of Tokyo Electric Power Company's large expansion program, for example, is the new Chiba Plant, scheduled to go into service late in 1956. Its initial capacity will be 125,000 kilowatts, produced by a single boiler-turbine-generator unit.

The boiler for this unit, being designed and built by Combustion Engineering, will be the largest boiler ever exported from the United States – and by far the largest in the Orient. It is a reheat boiler designed to produce 960,000 pounds of steam per hour, at a pressure of 2080 pounds per square inch and 1000° Fahrenheit, reheated to 1000°.

And the use of the *reheat* design in this important power plant – and in the three C-E Boilers being erected in other large Japanese power stations – exemplifies really progressive thinking. For the modern reheat cycle, which has had tremendous acceptance by power engineers throughout the world, is a leading factor in the production of electric power at lower cost.

C-E Boilers of postwar utility designs are now in service, under construction or on order in most areas of the free world. Thus today in Italy, France, Holland and Spain ... in Australia, Formosa, India and Korea ... as well as in principal countries of Latin America, the C-E trade mark has come to mean what it has long meant in the U.S.A. – highest standards of design and performance.

COMBUSTION ENGINEERING

C-E

Combustion Engineering Building
200 Madison Avenue
New York 16, N. Y.

B-817A

Boiler, fuel burning & related equipment; pulverizers, air separators & flash drying systems; pressure vessels; automatic water heaters; soil pipe

The illustration was drawn from a photograph of the Grand Bronze Buddha of Kamakura, courtesy of Japan Travel Bureau.

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 27 **No. 2**

August 1955

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GERALD S. CARRICK
Business Manager

JOSEPH C. McCABE
Editor
GLENN R. FRYLING
Associate Editor

CARL G. UDELL
Circulation Manager

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BPA

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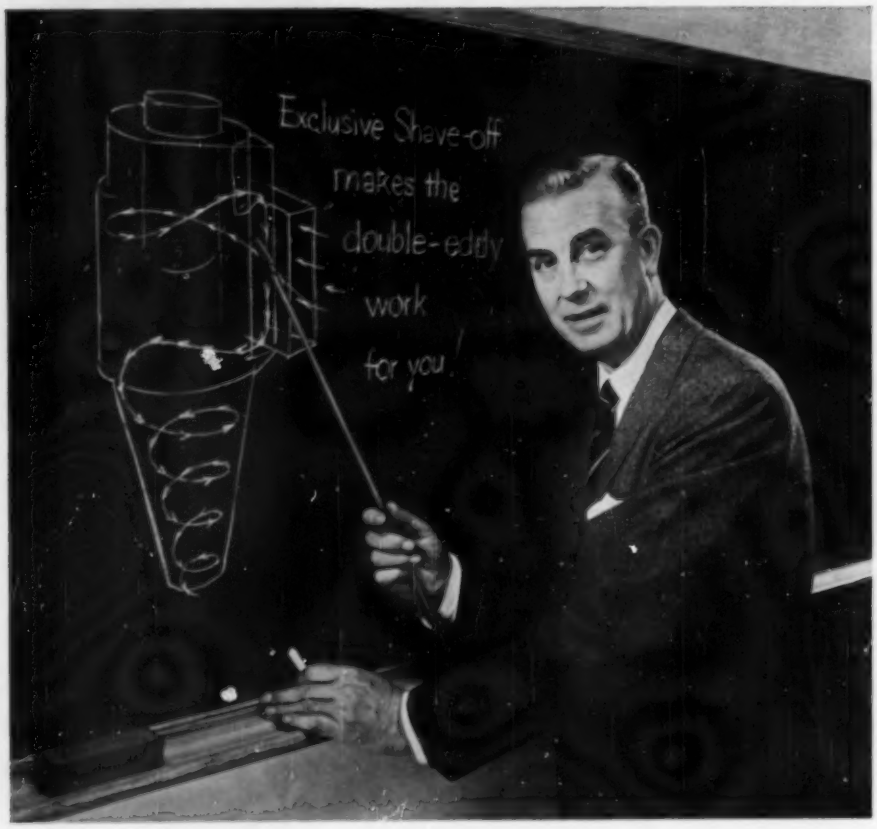
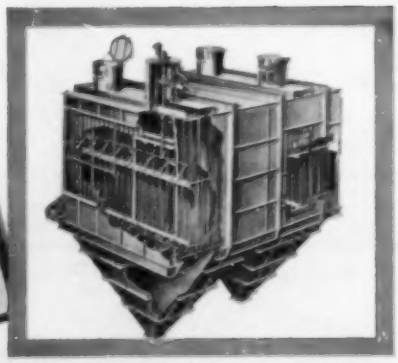
How Buell delivers the EXTRA PERCENT in Dust Collection Efficiency

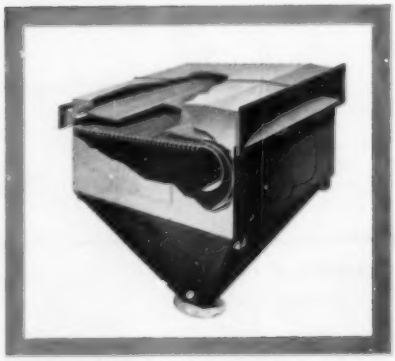


In any cyclone dust collector there is an upward eddy preventing the separation and dropping-out of a percentage of particles. But in Buell Cyclones, the exclusive Buell shave-off design *harnesses* this up-flow—puts it to work! Result: extra efficiency without extra operating cost!

For the complete story behind Buell's *extra efficiency*, write Dept 70-H, Buell Engineering Company, 70 Pine Street, New York 5, N. Y.



Buell's Low Resistance Fly Ash Collector combines top efficiency with low draft loss, for either natural or forced draft installations.

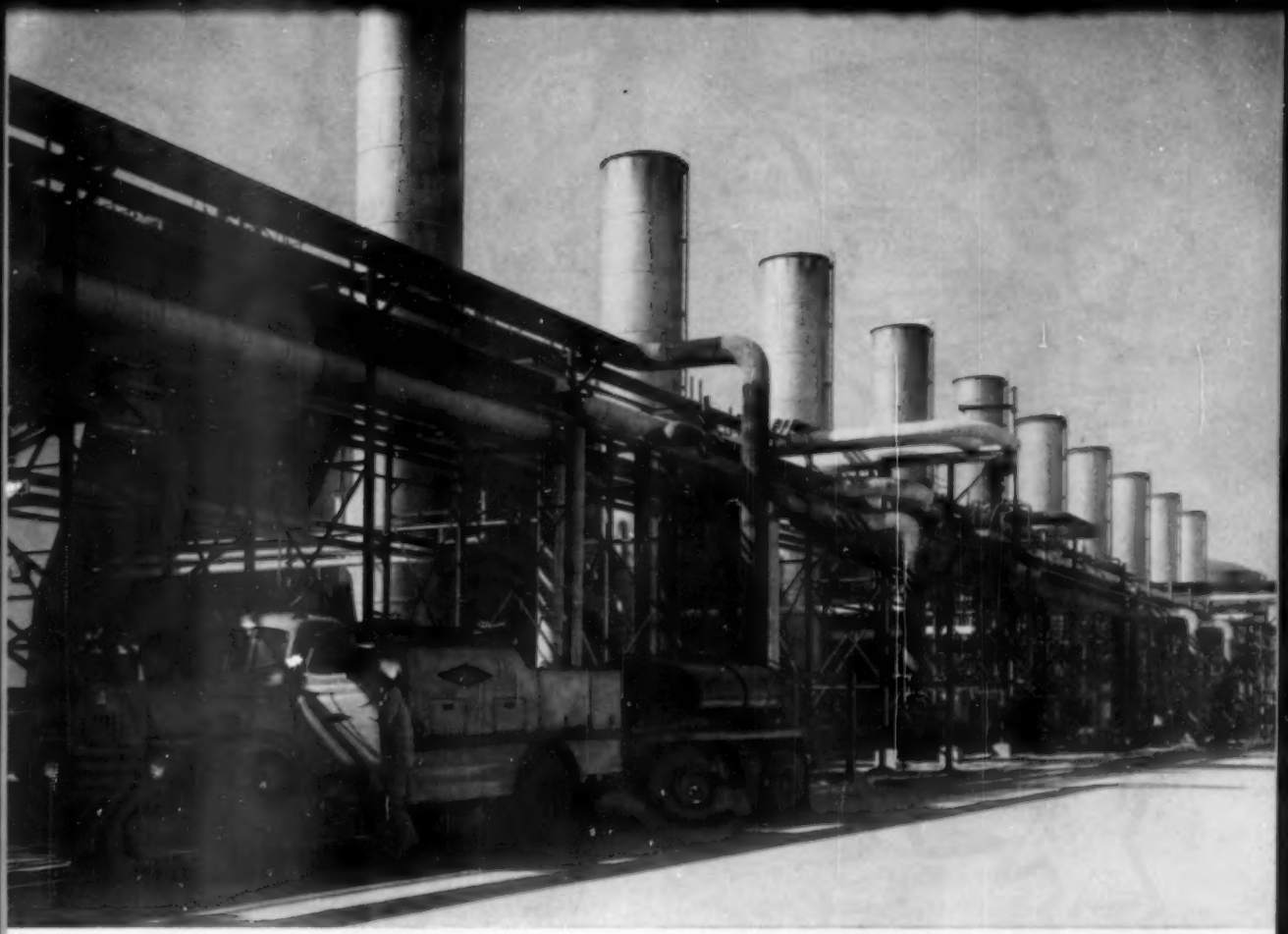


SF Electric Precipitator, a Buell exclusive, also delivers *extra efficiency* due to unique Spiralectrodes and continuous cycle rapping.

buell

MECHANICAL ELECTRICAL

Experts at delivering Extra Efficiency in **DUST COLLECTION SYSTEMS**



OPERATOR SAVED $440,000

DOWELL chemical cleaning of superheater avoided costly retubing and two-week boiler shutdown

Scale deposits had caused tube failures in the superheater of this 175,000-pound-per-hour boiler. To clean mechanically or replace the tubes would have required a two-week shutdown, costing $1,700 per hour in lost production. Instead, the operator chose Dowell chemical cleaning.

Experienced Dowell engineers developed special cleaning techniques for the nondrainable superheater, then used job-tailored Dowell solvents. The unit was restored to top operating condition in just 3½ days. Total saving to the operator, in cost of outage time and replacement parts, was approximately $440,000!

Dowell engineers hold downtime to a minimum by introducing solvents through regular connections. Extensive dismantling and scaffolding are not needed.

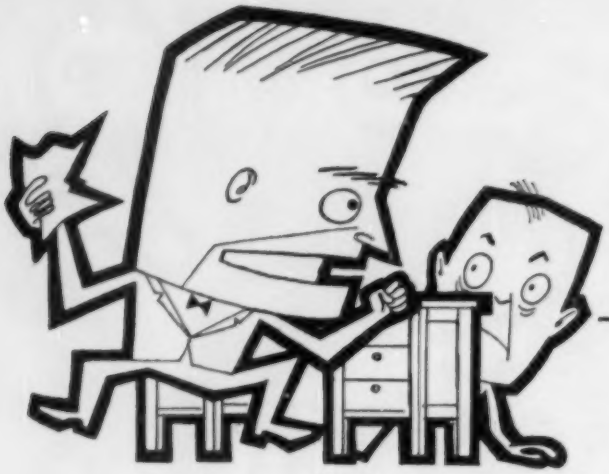
By removing corrosion products, chemical cleaning helps eliminate boiler tube failures due to overheating or galvanic attack. Prevent unscheduled shutdowns . . . keep your equipment operating at top efficiency . . . start a regular program of Dowell chemical cleaning *now*.

For more information, call any of the 165 Dowell offices in the United States and Canada. Or write directly to Dowell Incorporated, Tulsa 1, Oklahoma, Department H-25.

chemical cleaning service for industry

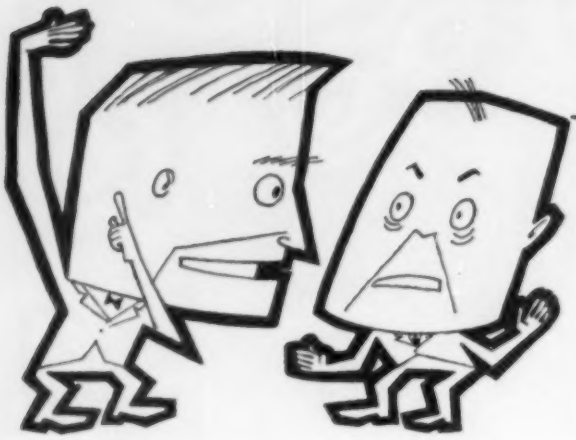
DOWELL

A SERVICE SUBSIDIARY OF THE DOW CHEMICAL COMPANY



Fire the fireman! Here's another smoke summons.

Don't fire the fireman, he's doing his best. Let us look for a more adaptable coal.



What's wrong with the coal? It's high in BTU's.

Sure, it's a good coal—in the right furnace—but our set-up just can't supply enough air to burn all of the hydrocarbons before they cool off and blow up the chimney as free carbon.

There's no sense in buying BTU's we can't burn, is there?

You've got a point there—and one that so many people are never aware of. It isn't only what's in the coal that counts—it's what you can get out of it under your own set of conditions. That's why picking the right coal is a job for a competent combustion engineer. The superior quality coal produced at mines served by the Chesapeake and Ohio will meet our most exacting requirements. Before we sign another coal contract, let's get in touch with coal producers on the C&O or a C&O coal man to give us the facts and figures on which coal will cost us least in the long run.

P.S.

There's a lot more to buying coal than the cost per ton. For facts and figures to solve your particular fuel requirements, write to: R. C. Riedinger, General Coal Traffic Manager, Chesapeake & Ohio Railway Company, Terminal Tower, Cleveland 1, Ohio.

Chesapeake and Ohio Railway

WORLD'S LARGEST CARRIER OF BITUMINOUS COAL

NEW DIMENSIONS IN CENTRALIZED CONTROL

Two story benchboard controls giant multiple fuel cyclone fired boiler!

The 125,000 KW extension to Raritan River Plant of Jersey Central Power and Light Company can be operated entirely from the compact benchboard shown here. This console, built by Hays and designed by Burns and Roe, Inc., consolidates the necessary control stations and miniature indicators in a small space yet provides easy accessibility for servicing.

In addition, this new design two story benchboard reduces costs three ways:

Lower operating costs—fewer men operate more equipment.

Lower installation costs—entire board fabricated by Hays. Minimum field piping and wiring.

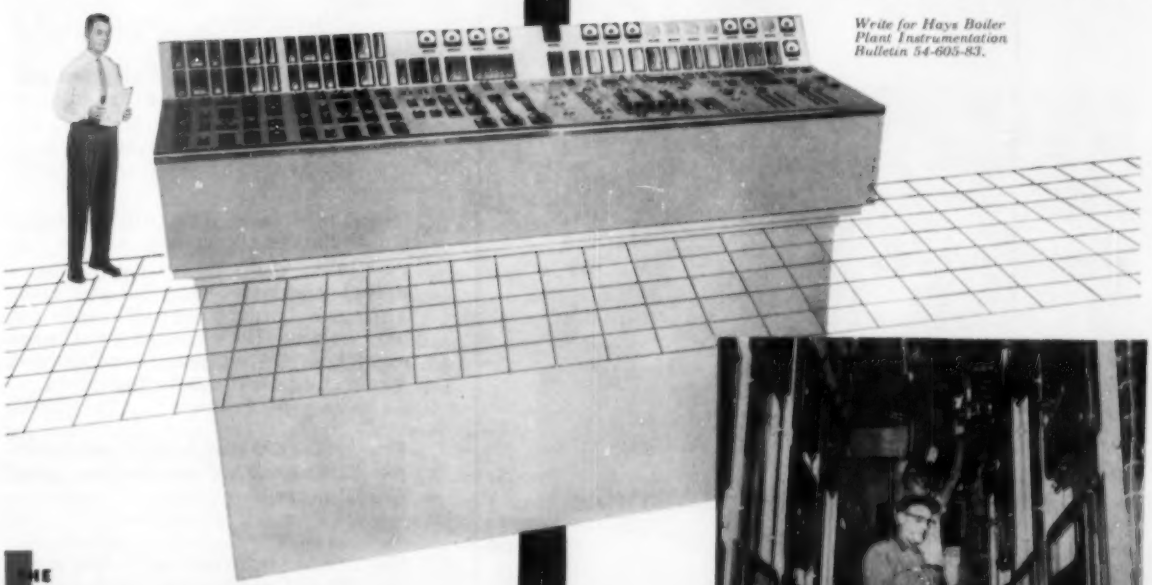
Lower maintenance costs—easy accessibility for maintenance from *inside* the panel (photo below).

Four cyclone furnaces are employed by the pressurized steam generator to deliver 900,000 lbs/hr. of main steam at 2,000 psig, 1050° F. and 740,000 lbs/hr. of reheat steam at 430 psig, 1000° F. The boiler is designed to burn coal and gas in any combination in all cyclones.

A Hays electrically operated combustion control system was selected by Jersey Central. Its electric operation eliminates the need for expensive compressors and dryers and allows maximum flexibility in central control location. Provision has been made in the system for future addition of oil as a third fuel with no loss in flexibility.

Hays paramagnetic type O_2 analyzers with new design sampling systems and electronic recorders are used for oxygen compensation of the control system.

Write for Hays Boiler Plant Instrumentation Bulletin 54-605-83.



Inside view of panel

THE **hays** CORPORATION

MICHIGAN CITY 1, INDIANA

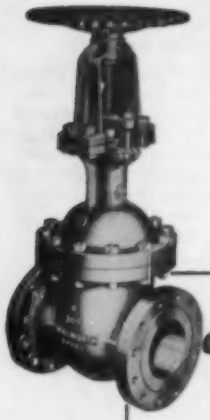
Automatic Combustion Control • Venturiflow Meters and Ventrol • Electronic Oxygen Recorders • CO_2 Recorders Boiler Panels • Gas Analyzers • Combustion Test Sets Draft Gages • Electronic Flowmeters • Miniature Remote Indicators • Electronic Feed Water Controls

WALWORTH

Cast Steel Gate Valves

Series 150 and 300

Wedge Gate — Outside Screw and Yoke



Sectional view of Series 300

Big 8-Point Superiority!

Gland clearances are such that stem cannot be scored if gland should be tightened unevenly.

Deep Stuffing Boxes in all sizes (2″ to 24″) insure tightness and maximum packing life — costly leaks are eliminated.

Bonnets and Bodies are engineered to withstand pressure and minimize distortion — they're tough, durable, dependable.

Heavy Steel Walls provide extra strength and longer life.

Integral Body Guide Rib Faces are machined to insure accurate disc seating.

Seat Rings are bottom seated — not flange type. No recess exists at back of ring — hence no turbulence, erosion, or pressure drop.

Streamlined Ports allow high velocity, non-turbulent flow, and reduce the possibility of erosion.

Valves regularly have flanged ends. They can be supplied with ends for butt welding. Roller bearing yokes are available. On valves 5 inches and larger, by-passes can be furnished.

For Series 600 and higher, we recommend Walworth Pressure-Seal Steel Gate Valves.

For further information on Walworth Cast Steel Gate Valves, see your local Walworth distributor, or write:

WALWORTH

valves and fittings

60 EAST 42nd STREET, NEW YORK 17, N. Y.

DISTRIBUTORS IN PRINCIPAL CENTERS THROUGHOUT THE WORLD

M. W. KELLOGG FLEXIBILITY ANALYSIS TECHNIQUES KEEP PACE

Increasingly high pressures and temperatures in central power stations call for increasingly accurate determination of the stresses and reactions of main and reheat piping. Thorough flexibility analysis eliminates the necessity of providing an excessive safety factor by overdesigning. This means shorter pipe runs—which decrease capital investment and increase operating efficiency.

M. W. Kellogg's special stress analysis group employs two basic techniques: (1) The general analytical method, involving development and solution of the requisite simultaneous equations for determining forces and moments in the piping system—calculated either manually or by an electronic computer; and (2) the unique Kellogg Piping Model Tester—which accurately simulates the operation of the most intricate piping systems under temperature.

The stress analysis group, originally formed in 1932, has become an integral function for many of M. W. Kellogg's power piping customers. The group is also available on a consulting basis. A recent booklet describes in detail Kellogg's various techniques for piping flexibility analysis. Copies are available on request.

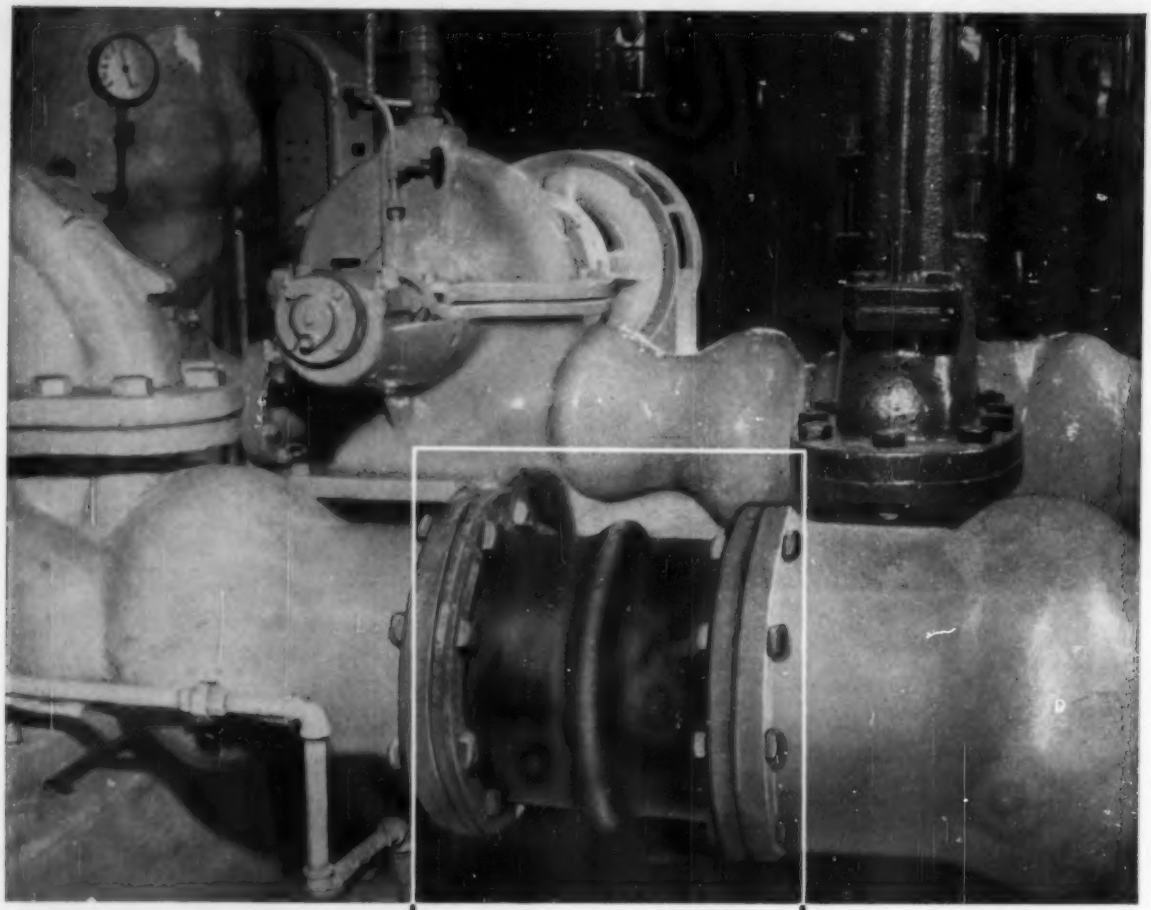
1. GENERAL ANALYTICAL SOLUTION—MANUALLY OR BY ELECTRONIC COMPUTER

2. THE UNIQUE KELLOGG PIPING MODEL TESTER

FABRICATED PRODUCTS DIVISION
THE M. W. KELLOGG COMPANY, 225 BROADWAY, NEW YORK 7, N. Y.
The Canadian Kellogg Company, Ltd., Toronto • Kellogg International Corporation, London
SUBSIDIARIES OF PULLMAN INCORPORATED

POWER PIPING—THE VITAL LINK

Teammates for 24 years—
U. S. Expansion Joints and a power plant!



Close-up of U. S. Expansion Joint installed on vacuum line, still working after 24 years.

When a large Midwestern power plant was opened in 1929, the vacuum lines were equipped with rubber expansion joints by United States Rubber Company, the original manufacturer of rubber expansion joints. And with the passing of time, the power plant installed additional U. S. Joints on house service pumps, condenser pumps and main circulating pumps.

U. S. Expansion Joints always give trouble-free operation because they have no moving parts to wear or bind. These economical, flexible connections are used in pressure or vacuum pipe lines in mechanical equipment to prevent excess stresses due to expansion or contraction. They also insulate against vibration, prevent the transmission of noise, and take care of misalignment.

"U.S." engineers at any one of 27 District Sales Offices will gladly help you on problems of this kind, or write to address below.

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"U.S." Research perfects it
"U.S." Production builds it
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GREEN
POWER AND PROCESS PLANT EQUIPMENT

AIRFOIL TYPE DRAFT FAN

M ost
E fficient
P oints of Six Designs ranges from 80-84 static efficiency

Those of you who have known GREEN for many years know that our ratings have always been conservative. You won't get less; often you get more.

With our *modernized* line of AIRFOIL Type Fans — we're calling them the GALEX Fans—we are following the same policy. Results—both test and operating—indicate our GALEX Fans will produce consistently high efficiencies. Static efficiencies are noted above. Mechanical efficiencies range from 84-88%. But with so many variables both in fan design and in operating conditions, buyers prefer the conservative ratings.

To this line of modernized, streamlined draft fans of the AIRFOIL Type, Green engineers bring more than 48 years of experience in designing and manufacturing draft fans. Actually, this AIRFOIL Type of Fan is nothing new to us. We made them in this country during the World War I era and many of those old AIRFOIL Type Fans are still in service. Today, some 35 years later, much more is known about fans and their behavior. Today, Green Fans are in an even stronger position to meet the requirements of the modern power plant.

We'll be glad to discuss your fan requirements with you and see which of the six AIRFOIL Designs would be best. With six designs, many combinations of volume and pressure are available.

GREEN THE AIRFOIL TYPE FAN Galex FAN

GREEN FUEL ECONOMIZER COMPANY, Inc.

BEACON 3, NEW YORK

BEACON PROCESSED POCAHONTAS

prepared in one of the largest, best equipped and most modern cleaning plants in the entire nation

Ask any group of coal users the fuel name they've known best and longest—and most will say "Pocahontas." It's been a famous name for almost a century, because coal from this field has been an acknowledged leader in cleanliness, good-burning properties, and all-round quality.

Beacon Processed Pocahontas Stoker Coal makes it possible for you to offer your customers something even better than this "best." One of the newest, largest, and best-equipped cleaning plants in the entire nation is at work at the Keystone mine, adding an *extra* touch of ultimate quality to the natural advantages of the fuel. This coal lets you say to your customers, "I'm giving you the finest thing in stoker coal it is possible to buy."

EASTERN GAS AND FUEL ASSOCIATES

PITTSBURGH • BOSTON • CLEVELAND • DETROIT • NEW YORK • NORFOLK
PHILADELPHIA • SYRACUSE

For New England: New England Coal & Coke Co.
For Export: Castner, Curran & Bullitt Inc.

STOKER COAL

SILENT

No grinding in the retort, with Beacon Processed Pocahontas Stoker Coal. It is sized to scientific standards, established after long tests in our own Stoker Coal Laboratory.

DUST PROOFED

This coal is naturally clean . . . but to eliminate any possibility of complaint from even the most finicky housewife, we dustproof with an oil spray.

SUPERLATIVE FEATURES

This fuel offers highest inherent quality; low volatile, which bans smoke; low ash which saves cost and complication; ideal clinkering properties; high heat output, with all the B.T.U.'s soaked up by the furnace or boiler; economy, because there's maximum available heat in every pound of coal.

Your next job of high-temperature or high-pressure piping merits the coordinated skills of Mitchell. You can give us the whole problem from start to finish, or participate—with our full cooperation, as you please. For assured satisfaction and economy, send us your drawings for estimate.

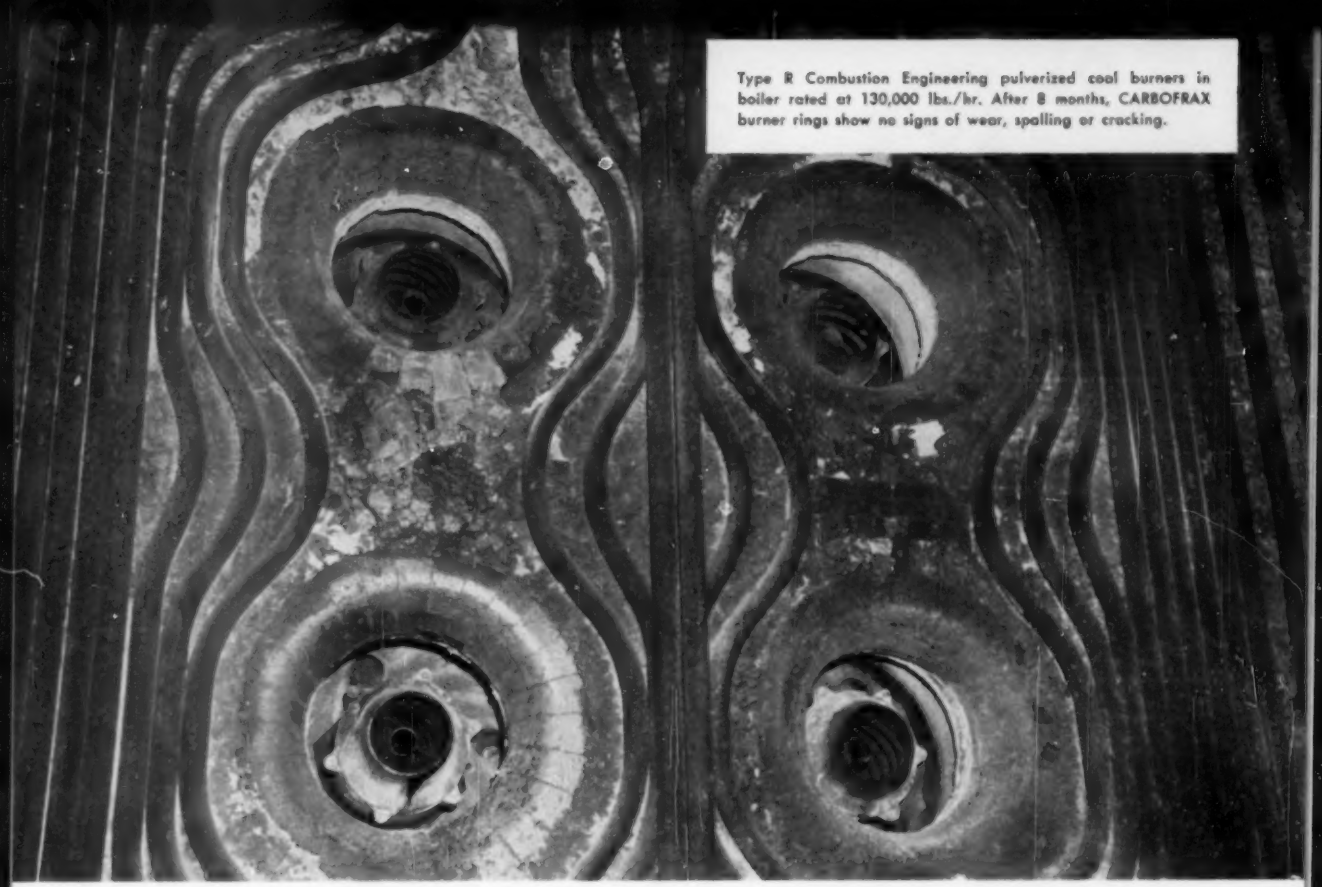
W. K. MITCHELL & CO., INC.

Philadelphia 46, Pa.

WESTPORT JOINT
(PATENTED)

MITCHELL PIPING
SINCE 1899

PIPING FABRICATORS AND CONTRACTORS



Type R Combustion Engineering pulverized coal burners in boiler rated at 130,000 lbs./hr. After 8 months, CARBOFRAX burner rings show no signs of wear, spalling or cracking.

This company proved to its own satisfaction that...

CARBOFRAX® burner rings outlast other types!

CARBOFRAX®
burner rings provide perfect flame patterns longer because . . .
• They won't soften, even at extreme temperatures, so slag never fuses to the burner ring.
• They take brutal punishment—with fewer repairs, replacements and shut downs (an out-of-line burner will have little effect on this ring).
• They resist abrasion, heat shock and flame erosion that rupture and erode other linings quickly.
• They eliminate flame-deflecting slag fingers.

They used a simple test. Burner rings of various refractory materials were placed in service.

Long after removing all others, one ring continued in use. This was built of CARBOFRAX silicon carbide shapes. The ring went on and on and on, proving its worth to the operator's own satisfaction.

In burner rings, in numerous other trouble spots, CARBORUNDUM's *Super Refractories can improve boiler efficiency . . . can relieve many operating headaches. More information is given in our booklet on Super Refractories for Boiler Furnaces. For your free copy write Refractories Division, The Carborundum Company, Perth Amboy, N. J. Dept. E85.*

CARBORUNDUM

Registered Trade Mark

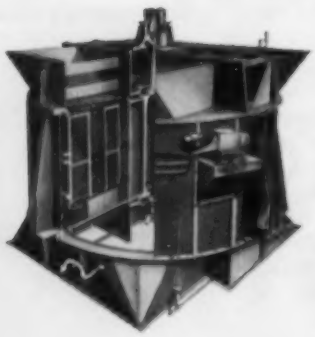
why you need less fuel with the Ljungstrom® Air Preheater

With every 45-50 F of air preheat — you cut your fuel bill 1%. That's why it pays to equip your boilers with Ljungstrom Air Preheaters. For the Ljungstrom is the most efficient air preheater there is.

Advantages of the Ljungstrom Air Preheater

- **Size for size, recovers more heat than any other type.**
- **Reduces fuel consumption. Permits use of lower-grade fuels. Increases boiler output and reliability.**
- **Eliminates cold spots . . . keeps corrosion to a minimum.**
- **Easier, faster to clean and maintain.**
- **Requires far less supporting steel and is quickly erected.**

The Ljungstrom also gives industrial plants broad latitude in their choice of fuels. Its unmatched preheating efficiency makes practical and effective such low-grade fuels as saw and paper mill refuse, wood, lignites, peat and bagasse.



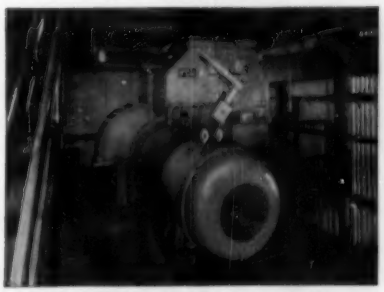
Outright fuel economy is reason enough why 7 out of 10 modern preheater installations are Ljungstrom, and why Ljungstrom percentage of installed boiler capacity increases every day. Yet it's just one of the many advantages of the Ljungstrom. Get all the details on why the Ljungstrom cuts fuel costs . . . why it's the most efficient heating surface on the modern boiler . . . why it's easier to clean and maintain. All the details are in the new, 38-page reference manual, "Ljungstrom Air Preheaters." Write for it, today.

The Air Preheater Corporation 60 East 42nd Street, New York 17, N. Y.

General View of Bay Front Steam Plant
Lake Superior District Power Co.
Sargent and Lundy
Consulting Engineers

Bartlett-Snow coal handling at Ashland

● The illustration above shows the first 38,600 KW unit of a plant which is to be extended into a 60,200 KW station. Coal is received by lake boat at a near-by deep water dock, and carried to the plant in railroad cars. All handling facilities including the track hopper and grillage, duplex feeder, conveyors, gallery, chutes, tripper and all supporting structures, were fabricated in our shops and installed by our erectors to Sargent and Lundy specifications. For maximum efficiency and fixed unit responsibility, let the Bartlett-Snow coal handling engineers work with you on your next job.



150 Ton Per Hour Ring Roll Crusher
Showing By-Pass Gate and Drive

Belt Conveyor Showing Automatic
Weightometer and Vertical Take-up

DESIGNERS ENGINEERS

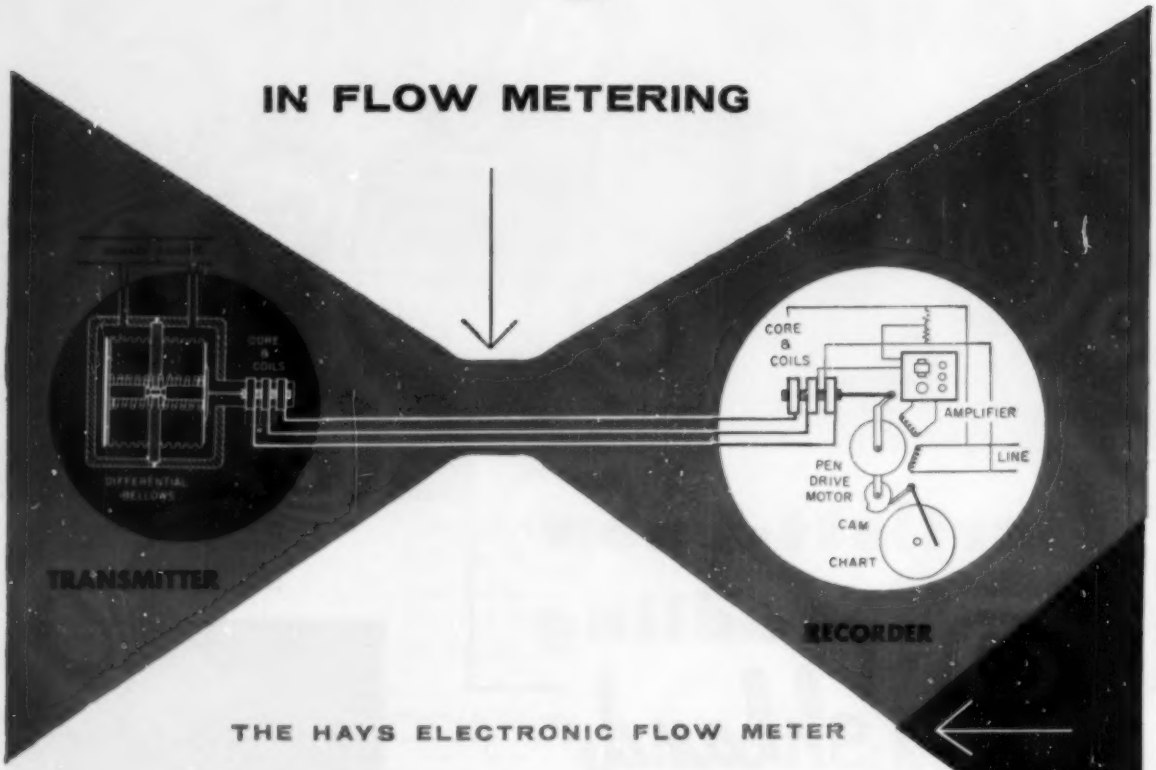
BARTLETT-SNOW
CLEVELAND 5, OHIO

FABRICATORS ERECTORS

"Builders of Equipment for People You Know"

new dimensions

IN FLOW METERING



THE HAYS ELECTRONIC FLOW METER

Here is a new Flow Meter—that is really new! These features of the Hays Electronic Flow Meter speak for themselves.

Mercuryless—costly mercury maintenance headaches eliminated—no mercury to lose.

Rupture-proof Bellows—provide positive protection against over-range.

Continuous integration—motor-driven continuous mechanical integrator is extremely accurate even on rapid load changes.

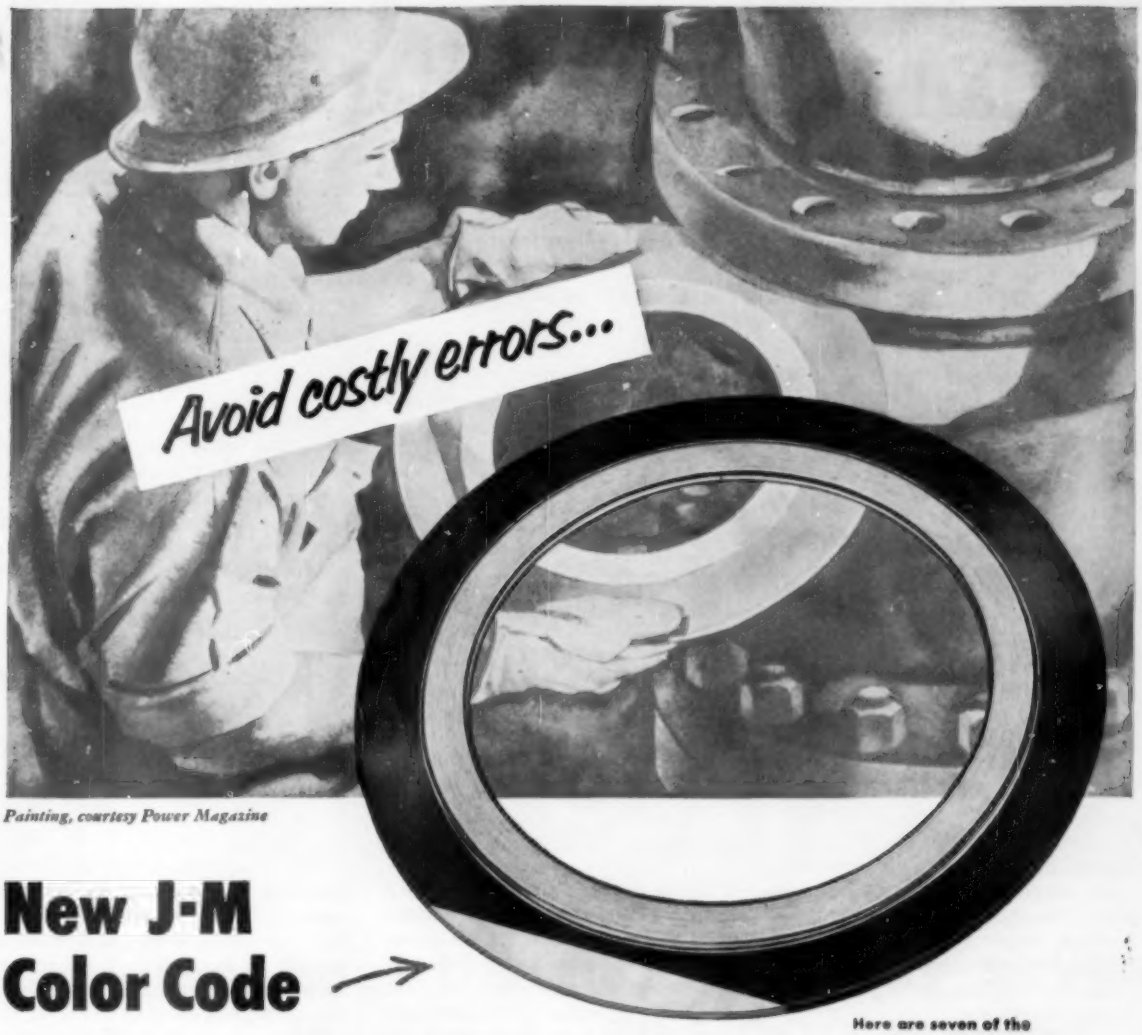
Electronic operation—requires only 4 seconds for full scale pen travel with accuracy of ¼% of full scale differential.

Other features include null-balance transmission, powerful motor, easy readability, accuracy unaffected by normal temperature changes. Explosion proof transmitters and wide range meters also available.

For complete information, write for Bulletin 54-1074-222.

hays
CORPORATION
MICHIGAN CITY 1, INDIANA

Automatic Combustion Control • Varriflow Meters and Ventrol • Electronic Oxygen Recorders • CO_2 Recorders Boiler Panels • Gas Analyzers • Combustion Test Sets Draft Gages • Electronic Flowmeters • Miniature Remote Indicators • Electronic Feed Water Controls



Painting, courtesy Power Magazine

New J-M Color Code

identifies metal in Spirotallic® Gaskets

Most engineers know that Spirotallic Gaskets maintain a perfect seal despite extreme fluctuation in fluid pressure and flange compression. Consequently, these gaskets are used in a wide range of service conditions which include high temperatures, elevated pressures and active corrosives. To withstand these conditions, Spirotallic Gaskets employ a variety of corrosion-resistant alloys.

Because so many of these metals look alike, only expensive tests or costly experience with the gasket could determine the gasket metal used, once its identifying tag was lost. Now the color patch on the centering guide tells the metal employed and saves time, trouble and expense. This new method of identification also makes it easier for storekeepers and mechanics who handle the gasket. In addition, it simplifies inventories.

Spirotallic Gaskets hold their seal because they are made of spirally wound interlocking plies of asbestos and spring-like metal strip. These gaskets compress easily with light bolting. For catalog PK-35A and copy of color code card write Johns-Manville, Box 60, New York 16, N. Y. In Canada, Port Credit, Ont.

Here are seven of the metals available and their color identifications

Zinc-coated steel—white

Type 304 Stainless—yellow

Type 316 Stainless—green

Type 347 Stainless—blue

Monel—orange

Copper—brown

Aluminum—aluminum

Johns-Manville SPIROTALLIC GASKETS

HALL LABORATORIES, INC.—A SUBSIDIARY OF HAGAN CORPORATION, PITTSBURGH, PENNSYLVANIA

Hall Industrial Water Report

VOLUME 3 AUGUST 1955 NUMBER 4

It Takes a Lot of Water Conditioning To Operate a Steel Mill at Capacity Plus

The constantly increasing production of steel demands a constantly increasing stream of raw materials. Water, used in many ways, is one of the most important. More than 100 tons of water go into the production of every ton of steel, underlining the importance of water engineering to the steel industry. Hall Laboratories, through close cooperation with plant personnel, serves the steel industry, whether in routine control of daily treatment, or in solving the many special problems peculiar to the steel industry.

The Skid-Pipes Were Skidding

Difficulties with cooling water constitute the bulk of steel plant water problems. For example, in one steel plant, the water cooled skid-pipes on which billets are pushed through 2000°F reheating furnaces were buckling.

Investigation revealed that scale formation cut down heat transfer and caused the overheated pipes to fail. Threshold Treatment of the cooling water with Calgon® now keeps the skid-pipes free of scale, and the buckling of the pipes is no longer a problem.

Discoloration of Galvanized Strip Checked

Hall engineer B. Q. Welder reports on solution of a problem in the galvanizing mill of a large steel mill in the "Iron City."

"Galvanized strip unaccountably developed large dark discolorations some weeks after shipment. It seemed to me that the source of the discoloration might be in the rinsing operation.

"Following galvanizing, the strip was rinsed by immersion in and spraying with filtered river water. The last step in the process was a chromate-silicate rinse prepared with clarified river water. Carryout of solids from the rinses was responsible for the trouble.

"Since adopting our recommendation that condensate be used for the rinse following the immersion tank and in making up the final chromate-silicate rinse there have been no further reports of trouble."

Baffling Problem Solved

When the exchange capacity of a sodium zeolite softener in an eastern steel mill dropped to 8.2 kilograins per cubic foot from a rated capacity of 16 kilograins per cubic foot, plant personnel consulted their Hall engineer, D. E. Noll. To confirm his suspicion that hydraulic channeling of the resin bed was responsible for the loss of capacity, Noll tried an intermediate backwash to redistribute the resin. The backwash doubled the length of the run, indicating that channeling might be the trouble.

When operation permitted an inspection of the resin bed, Noll and the plant men found that although fissures had not broken through, high flow rates around the edges of the unit had pushed down the exchange material, and a cone had formed in the bed.

To step up the efficiency of the softeners, Noll suggested a baffle design that would insure even distribution of the incoming water throughout the exchange bed. When the units were returned to service with baffles installed, the exchange capacity came up to the rated 16 kilograins per cubic foot and normal regeneration practice was resumed.

Specialists in iron and steel metallurgy are skilled at transforming crude ore into finished metal. Like the technologists in steel, Hall Laboratories fits the treatment of a vital raw material, water, to the need in specific processes in the manufacture of steel.

New Control System Tested

A new system of automatic blowdown control developed by Hall Laboratories' research has shown in field trials that it maintains boiler water solids concentration within plus or minus 5% of the set point.

The equipment continuously determines the dissolved solids concentration in boiler water by measuring the conductivity of a flowing sample. A signal from the conductivity cell pneumatically controls the blowdown valve.

The new control system minimizes the possibility of carryover and allows close control of treatment under all conditions.

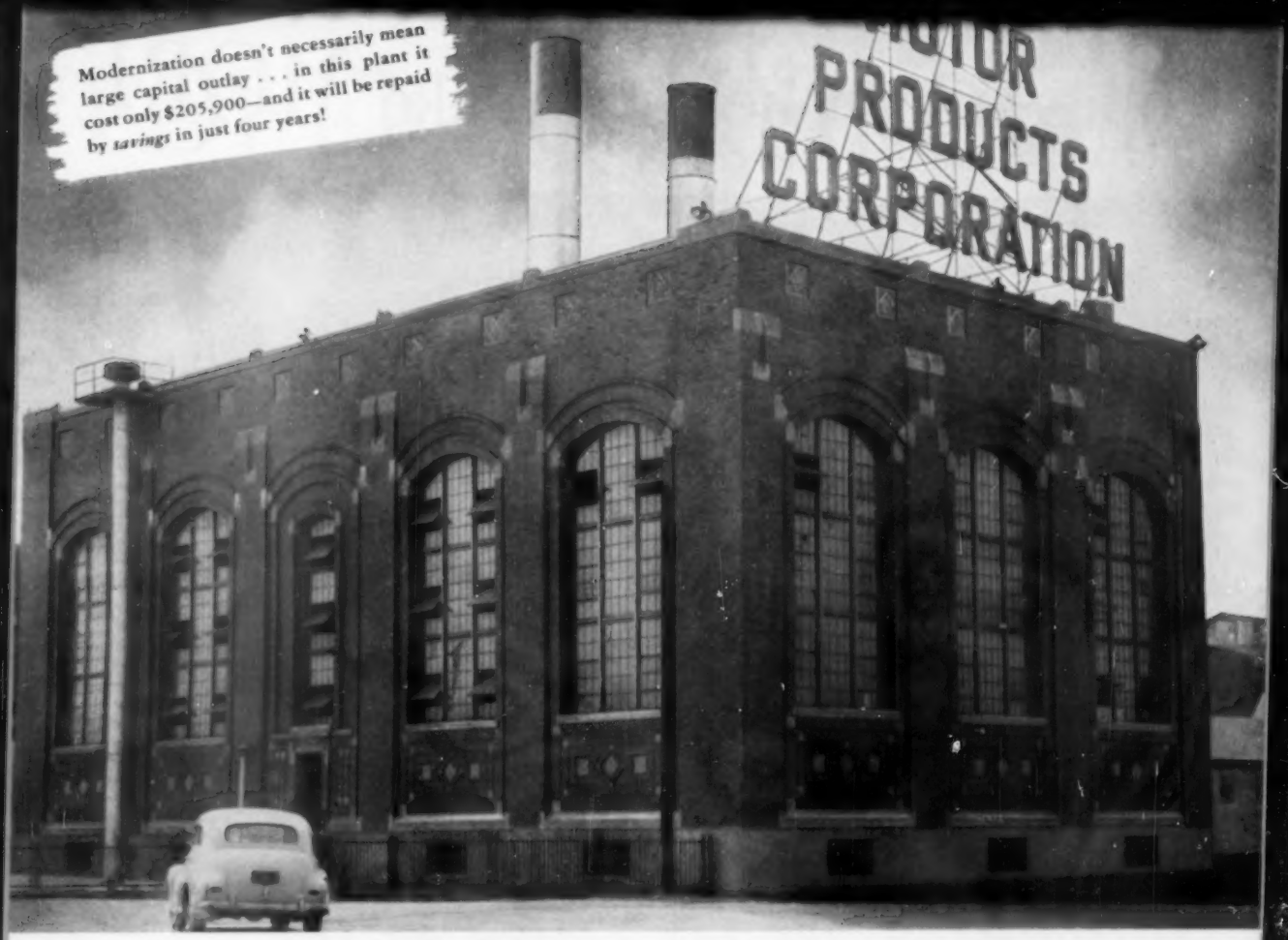
Booklet H-1, describing the Hagan Automatic Blowdown Control System, is available upon request.

Industrial Water Problems Require Special Handling

There are no "stock answers" to industrial water problems. For information, write, wire or call Hall Laboratories, Inc., Hagan Building, Pittsburgh 30, Pa.

Water is your industry's most important raw material. Use it wisely.

Hall Laboratories, Inc.—Consultants on Procurement, Treatment, Use and Disposal of Industrial Water


Modernization doesn't necessarily mean large capital outlay . . . in this plant it cost only $205,900—and it will be repaid by *savings* in just four years!
PRODUCTS
CORPORATION

Burning coal the modern way saves Motor Products $54,000 a year

Faced with poor boiler control, air pollution difficulties, inefficient coal and ash handling and other costly defects in its outmoded power system, Motor Products Corp., Detroit, called in local consultants to make a study. The engineers recommended a modernization program, involving some new equipment along with the adaption of existing units to new systems.

This modernization is saving Motor Products time, labor, and money—better than $54,000 per year. Now the entire operation is clean and efficient. Production of economical steam is faster, simpler, more reliable and well within the bounds of smoke and dust regulations.

Investigate Your Fuel Costs

If you're planning to modernize your plant or build a new one—or if you are just interested in cutting fuel costs—find out how coal, burned the modern way, compares to other fuels. Why not talk to a consulting engineer or your nearest coal distributor? Their advice may save you thousands of dollars each year.

facts you should know about coal

Up-to-date coal burning equipment can give you 10% to 40% more steam per dollar.

Automatic coal and ash handling systems can result in a virtually labor-free plant.

Coal is the safest fuel to store and use. No dust or smoke problems when coal is burned with modern equipment.

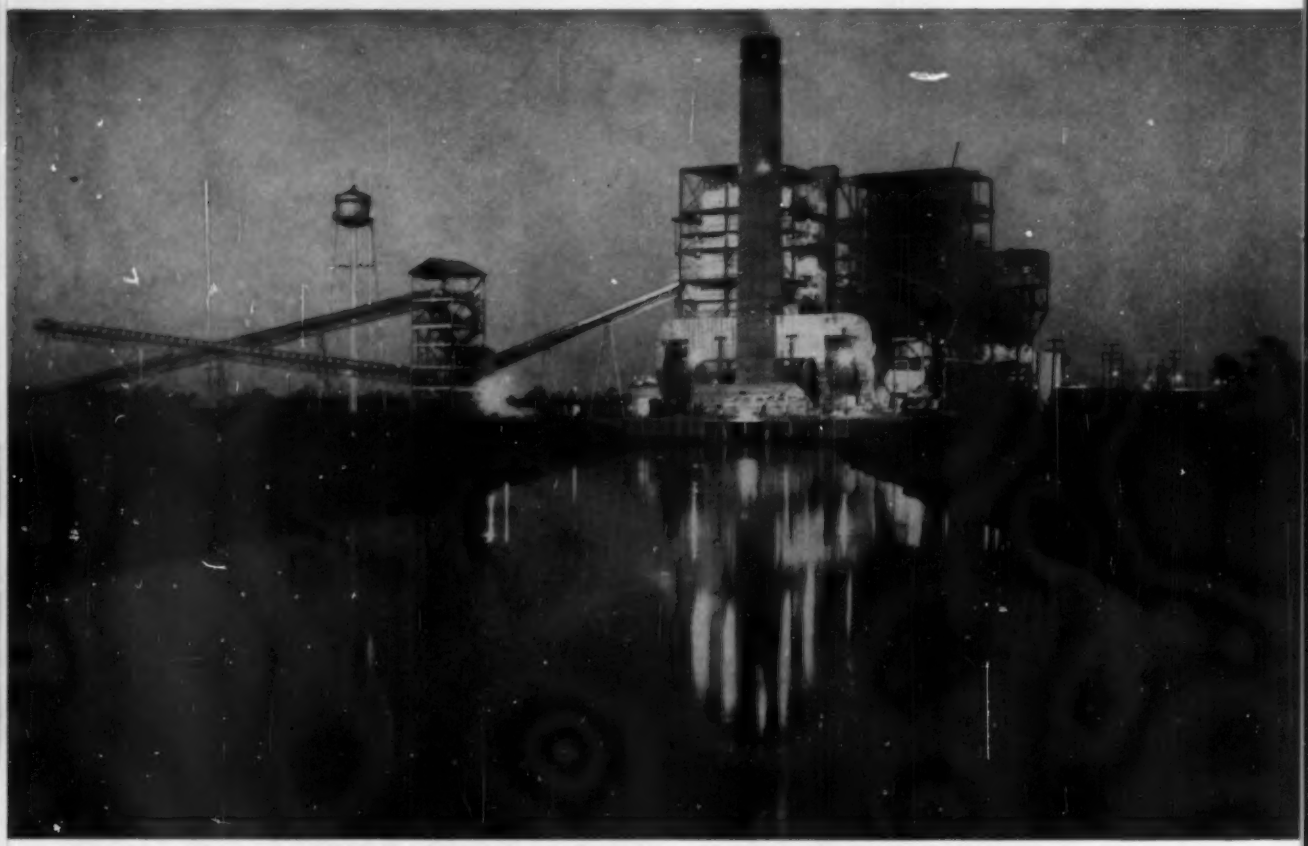
In most industrial areas, bituminous coal is the lowest-cost fuel available.

Between America's vast coal reserves and mechanized coal production methods, you can count on coal being plentiful and its price remaining stable.

For further information or additional case histories showing how other plants have saved money burning coal, write to the address below.

NATIONAL COAL ASSOCIATION
Southern Building, Washington 5, D.C.

Copes-Vulcan helps to make MORE

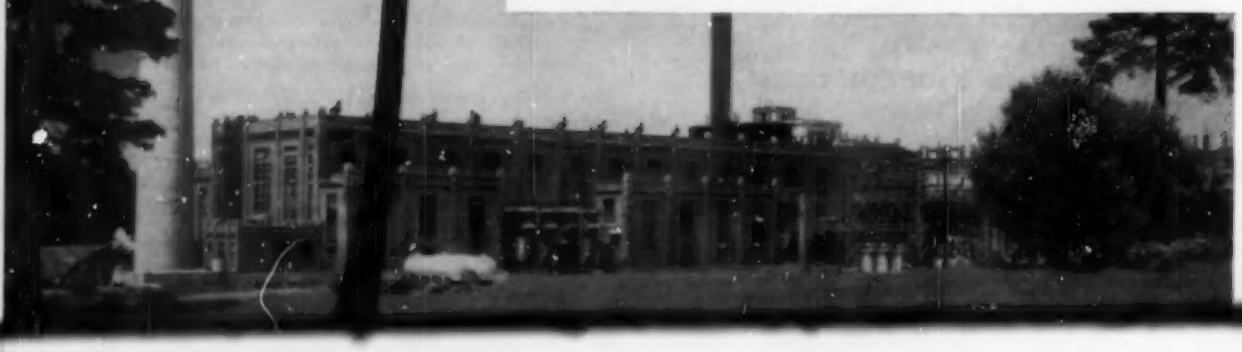


THE ALL-OUTDOOR Louis V. Sutton Steam Electric Generating Plant of the Carolina Power & Light Company at Wilmington, N. C. Copes-Vulcan Combustion Control, Boiler Feed Water Control, and Automatic-Sequential Soot Blowing help to maintain maximum boiler efficiency.

REPEAT ORDER for Copes-Vulcan Boiler Control and Pump Recirculation

from Carolina Power and Light Company for the Cape Fear Steam Electric Station

Copes-Vulcan maintains perpetual interest in every installation *after* it is in service. And throughout the life of the equipment, trained Copes-Vulcan servicemen will regularly visit the plant to check performance and see that everything is functioning as it should. If you'd like this attention on your jobs, give Copes-Vulcan a crack at the control and cleaning of your next boiler.



POWER FOR CAROLINA

At Carolina Power & Light Company's new outdoor installation, the Louis V. Sutton Steam Electric Generating Plant, steam is generated in two coal-fired boilers designed for 1750 psi at 1005 F. Unit 1 is a Combustion Engineering steam generator with a design load capacity of 950,000 pph. Unit 2 is a radiant-reheat Babcock & Wilcox boiler designed for 900,000 pph, with a reheat to 1005 F. Copes-Vulcan control helps keep these steam generators efficient.

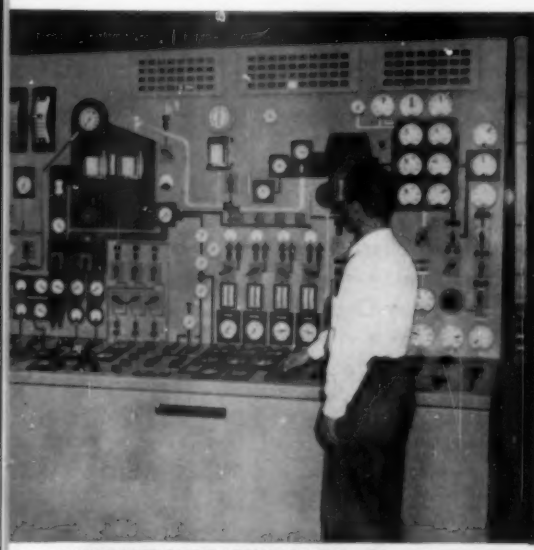
BOILER CONTROL

A Copes-Vulcan Combustion Control System accurately regulates the fuel and air for proper combustion. Copes Type 3-L Feed Water Control matches the feed flow to the steam demands and maintains a constant drum level. Copes provided 10-inch, 1500 pound standard motor-operated feed water by-pass control valves. Copes-Vulcan control and valves give automatic recirculation for protection of three boiler feed pumps.

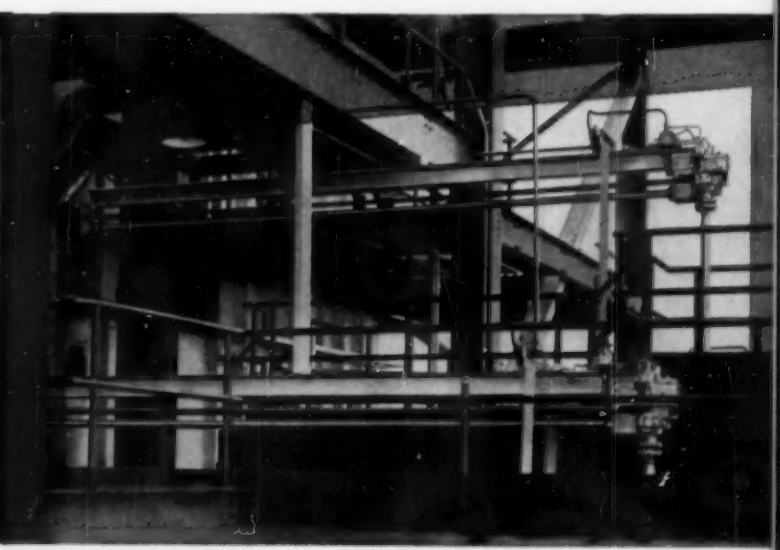
BOILER CLEANING

The Vulcan Automatic-Sequential Soot Blowing thoroughly cleans the heating surfaces. Air is the blowing medium in both units. Air motors drive the blowers in Unit 1; Electric motors drive those in Unit 2. Cleaning elements include Vulcan long retractables, wall deslaggers, rotaries, and air preheater cleaning controls.

Write for complete information about Copes-Vulcan Boiler Controls and Soot Blowers.



COMPACT OPERATING PANEL. There is one operator in the central control room at the Louis V. Sutton Generating Plant.



DUAL-MOTOR DRIVE on these Vulcan Long Retractables and the Vulcan Wall Deslaggers give more complete cleaning than single-motor drive, leaving *no* surface unblown.

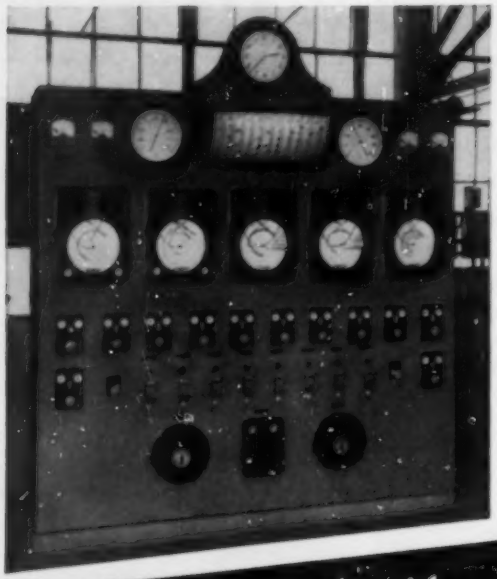
COPES-VULCAN DIVISION

CONTINENTAL FOUNDRY & MACHINE COMPANY

ERIE 4, PENNSYLVANIA

We believe
ONLY THE HIGHEST QUALITY OF PRODUCT AND SERVICE TO OUR CUSTOMERS CAN BUILD A REPUTATION WORTHY OF OUR EFFORT.
Copes-Vulcan

COPES VULCAN



This Bailey Boiler Control Panel in a mid-western industrial plant saves fuel and insures safe operation of a 100,000 lb per hr, 175 psi, sat., pulverized coal and gas-fired boiler.

What's Your Control-Dollar Efficiency?

Control-dollars frequently bring annual investment returns of 100% or more. When you buy adequate, well-applied steam plant controls, you increase your dollars' ability to work usefully for you.

That's where Bailey can help: Bailey Controls can give you a better control-dollar efficiency. Here's why:

1. **Complete Range of Equipment—fully co-ordinated.** You need never worry that a Bailey Engineer's recommendation is slanted in favor of a particular type of equipment, just because he has a limited line to sell—or that Bailey will pass the buck for efficient control; we offer *complete* boiler control systems.

2. **Engineering Service—backed by experience.** No other manufacturer of instruments and controls can offer as broad an experience, based on successful installations involving all types of combustion, flow measurement and automatic control.

3. **Direct Sales-Service — conveniently located near you.** Bailey Meter Company's sales-service engineers are located in more industrial centers than those of any other manufacturer of boiler control systems; you get prompt, experienced service with a minimum of travel time and expense.

•

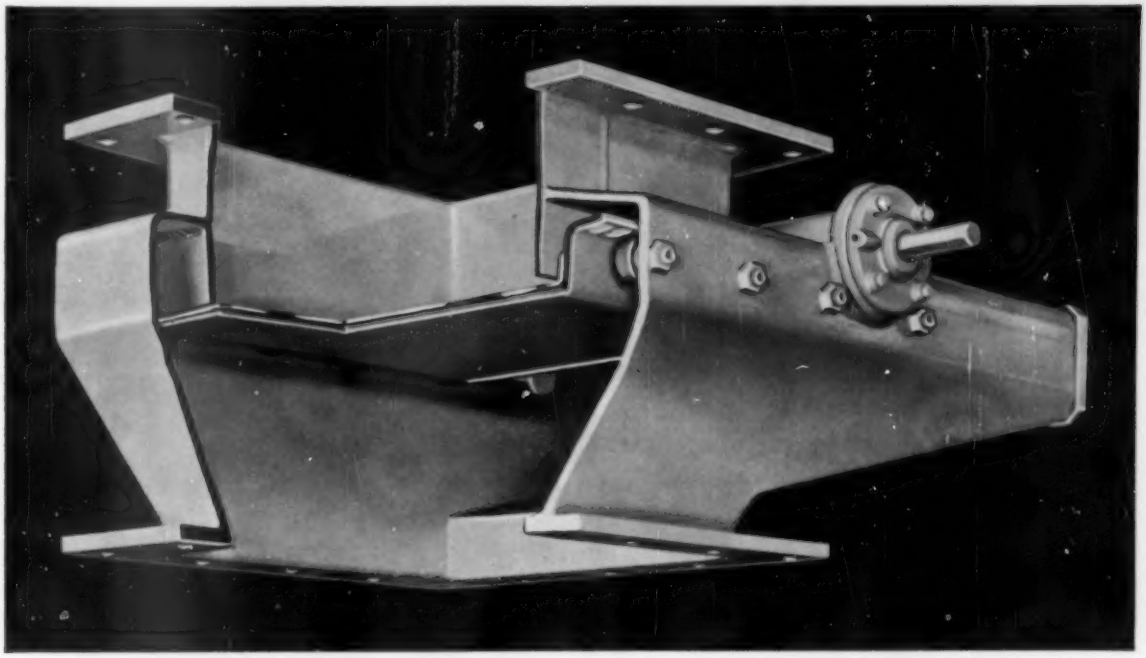
For better control-dollar efficiency—for more power per fuel dollar, less outage and safer working conditions, you owe it to yourself to investigate Bailey Controls. Ask a Bailey Engineer to arrange a visit to a nearby Bailey installation. We're proud to stand on our record: "More power to you!"

A-112-1

BAILEY METER COMPANY

1025 IVANHOE ROAD
CLEVELAND 10, OHIO

Controls for Steam Plants
COMBUSTION · FEED WATER
TEMPERATURE · PRESSURE
LIQUID LEVEL · FEED PUMPS



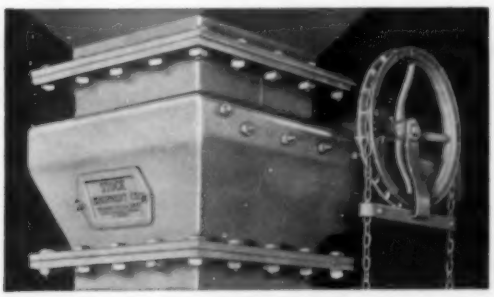
Here's The Inside Story On The New
S-E-CO. Coal Valve

Strip the ⅜" steel skin off our new coal valve and you'll quickly see why *you get more when you buy S-E-Co.*

First, notice the deep U-shaped gate which completely shields rollers, racks and pinions from coal flow. See how the gate provides lap closure on all four sides assuring positive cut-off. Also, note the stainless steel liner on top side of the gate to combat corrosion.

Carefully formed ladder racks, for their part, are self-cleaning having no root portion in which coal dust can build up and cause jamming. The multi-faced pinions, located above the racks, are also of self-cleaning design. Consequently, the gate moves smoothly with little effort, even after long periods of not being operated.

Notice the clean interior design. Slopes have been kept at a maximum with shoulders and projections eliminated. Even the poke hole covers fit flush with the inside of the valve body so that nothing interferes with flow of coal through the valve.



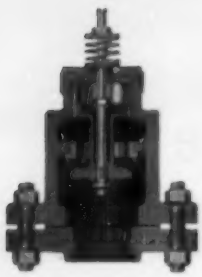
For a complete list of all the outstanding features of the new S-E-Co. Coal Valve together with installation photographs and dimensions, write for Bulletin No. 97.

STOCK Equipment Company

745-C, HANNA BLDG., CLEVELAND 15, OHIO

BAYER
STEPS UP BOILER PERFORMANCE

DISTINCTLY DIFFERENT



Bayer Balanced Valves are famous for their long life and continued tightness.

Bayer Single Chain Balanced Valve Soot Cleaner

WITH THE Bayer Balanced Valve Soot Cleaner the balancing chamber above the piston disc impounds steam when the valve closes, thus relieving valve parts from shock. The valves remain ***steam tight*** because the dashpot action causes the valve to seat gently. Unbalanced valves close with a hammer stroke and soon become leaky.

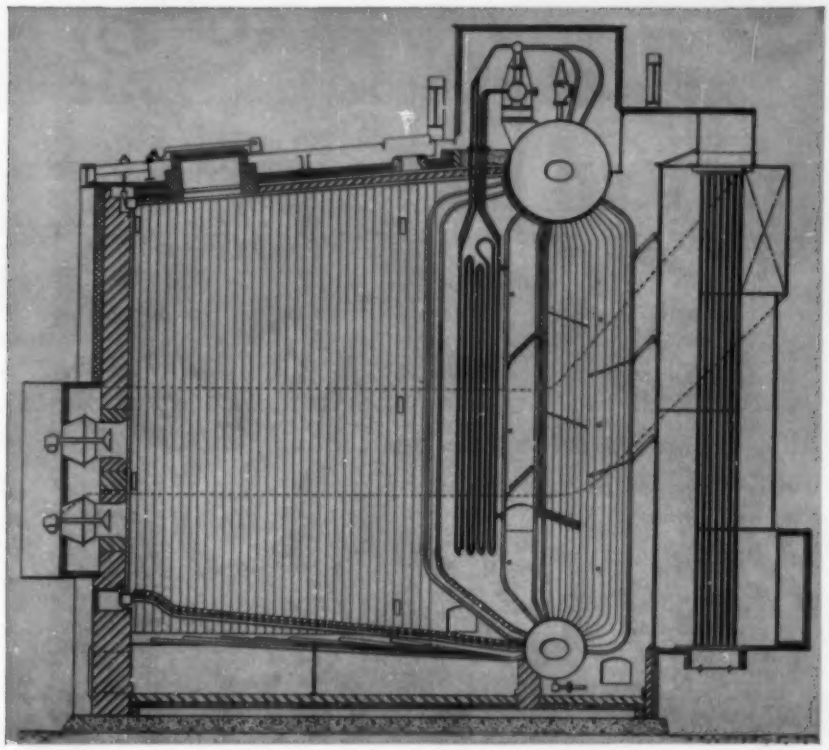
When stationary elements are used the Bayer stationary balanced valve head may be furnished. Thus all the cleaning elements of the entire soot cleaner system can be controlled by the Bayer quick-opening Balanced valves. This gives a uniform or standard valve controlled system and in addition, when high pressures require a reduction in pressure *at each individual element* this Balanced valve unit, whether used with a stationary or a revolving element, can be fitted with an integral orifice plate valve.

Piping connections can be kept in the same plane and undesirable bends or fittings avoided when the Bayer Balanced Valve is installed with both stationary and revolving elements.

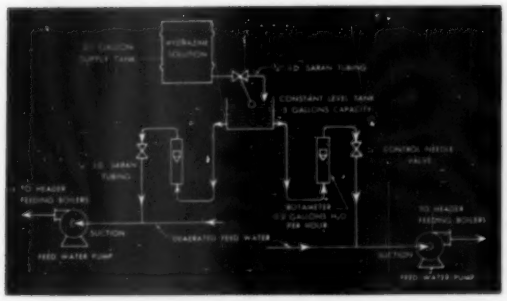
Valve parts are standard and interchangeable and when high pressure heads are fitted with orifice plate regulating valves these parts are also interchangeable.

THE BAYER COMPANY

SAINT LOUIS, MISSOURI, U. S. A.



protect industrial boiler systems from oxygen corrosion with DIHYDRAZINE SULPHATE



The powerful reducing action of hydrazine hydrate as an oxygen scavenger in boiler feedwater is now obtainable through the use of a salt—dihydrazine sulphate. This compound, a dry material in white crystalline flake form, contains 37½% hydrazine (N_2H_4) by weight and is shipped in 200-lb. and 20-lb. fibre drums requiring no I.C.C. warning label.

In preventing corrosion caused by dissolved oxygen, dihydrazine sulphate improves the quality of process steam by reducing iron pickup. It is conveniently applied by dissolving in deaerated condensate and feeding the solution directly to the feedwater entering steam boilers. It may also be used as an ingredient of boiler compounds.

Literature on the advantages of hydrazine derivatives in steam systems will be sent on request. Write for this helpful information today.

3060-A

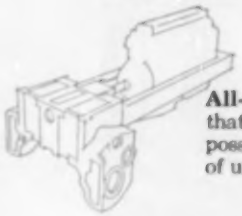
MATHIESON

MATHIESON CHEMICALS
OLIN MATHIESON CHEMICAL CORPORATION
INDUSTRIAL CHEMICALS DIVISION • BALTIMORE 3, MD.

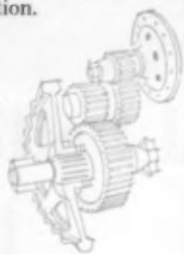
Allis-Chalmers presents the new

ANOTHER BIG STEP AHEAD IN LOW-COST COAL HANDLING

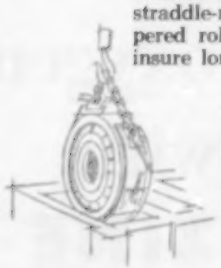
. . . with all the important performance advantages of Allis-Chalmers advanced basic design . . . tested and proved over millions of operating hours!



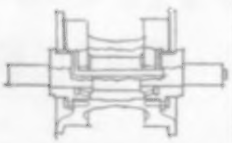
All-Steel Box-A Main Frame that soaks up shock loads, makes possible the service simplicity of unit construction.



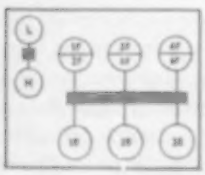
Exclusive One-Piece Steering Clutch and Final Drive Housing with all final drive gears straddle-mounted on tapered roller bearings to insure long life.



Unit Construction lets you remove engine, master clutch, transmission, steering clutches and final drives without disturbing adjacent parts.



1,000-Hour Lubrication Intervals for roller bearing truck wheels, idlers and support rollers . . . makes production time out of service time.



Dual-Range Constant-Mesh Transmission lets you go from any forward speed to any reverse speed by shifting only one lever. Eliminates double shifting! That means faster work cycles . . . more production!

plus . . . these great new features:

New Allis-Chalmers Diesel Engine with "follow-through" combustion and tornado turbulence . . . for smooth engine performance, cleaner combustion, extra long engine life.

New Wrap-Around Radiator Guard used as dozer lift frame to simplify design, reduce cost of bulldozer; guard tilts forward for easy service.

New Master Clutch with Ceramic Lining sets new standards of clutch life . . . with fewer adjustments required.

New Operator Convenience including roomy, flat platform . . . foam rubber seat . . . 24-volt direct electric starting . . . 60-gal. fuel tank.

Tough New Track — New design, through-hardened with extra toughness for long life even in severe abrasive conditions.

PLUS . . . new, all-weather cooling; independent radiator-core mounting; new strength and capacity in final drive gears, shafts and bearings.

NEW STANDARDS OF PERFORMANCE AND LONG LIFE ON A WIDE RANGE OF JOBS

You owe it to yourself to investigate the performance advantages of the HD-11 . . . newest addition to the Allis-Chalmers leadership line. See your nearby Allis-Chalmers dealer now.

HD-11

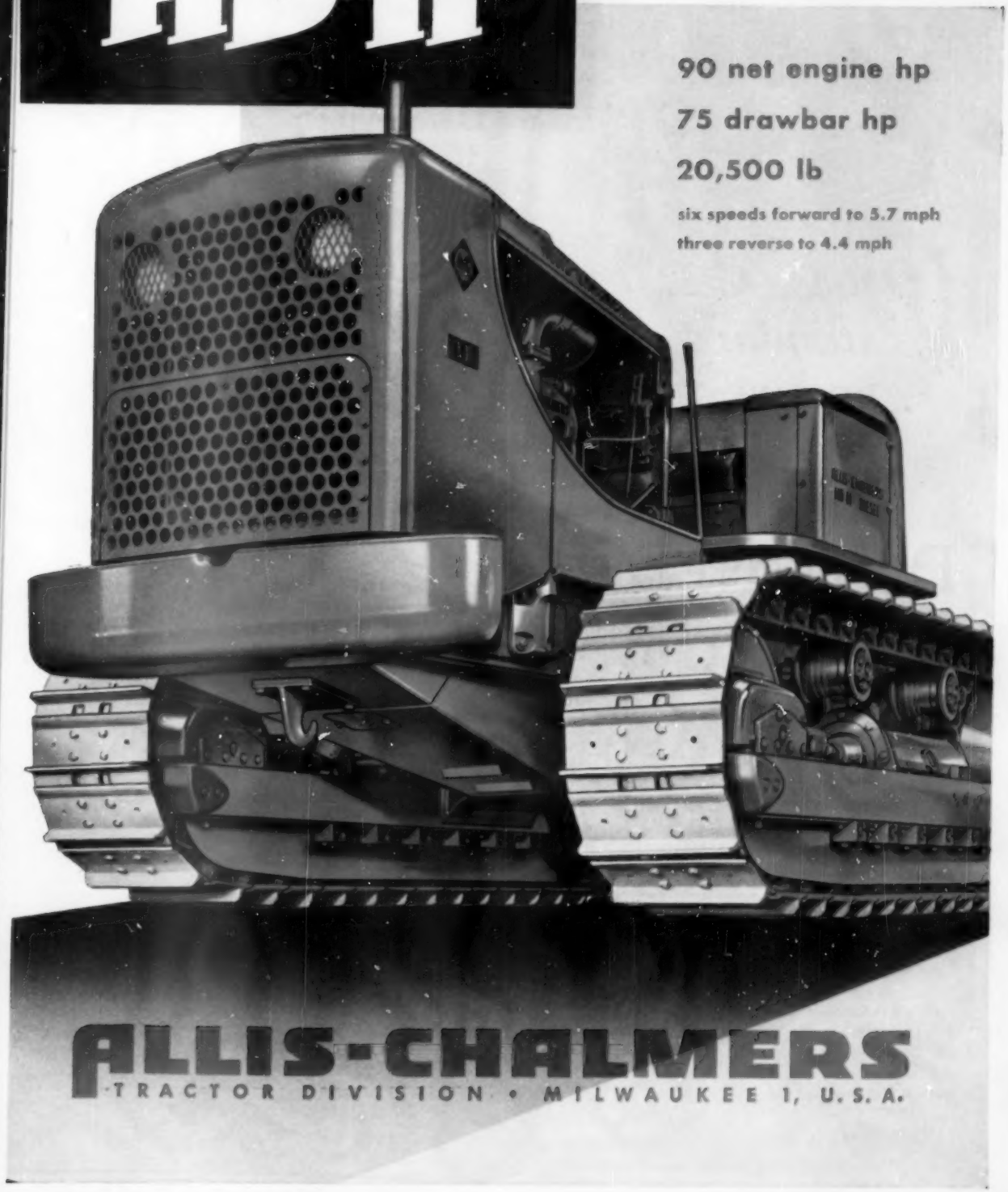
90 net engine hp

75 drawbar hp

20,500 lb

six speeds forward to 5.7 mph

three reverse to 4.4 mph



ALLIS-CHALMERS

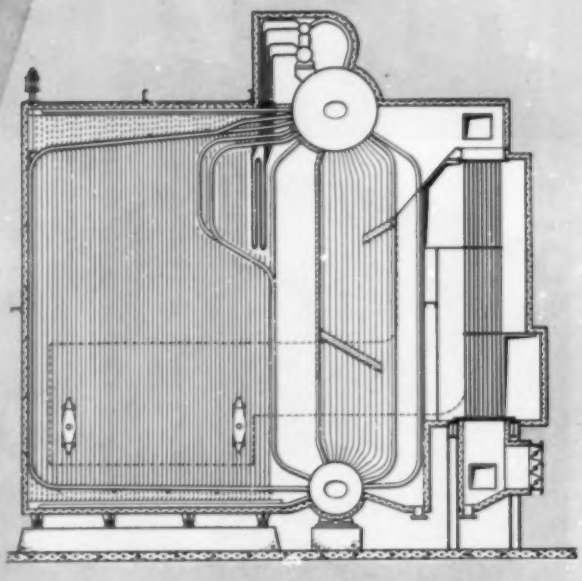
TRACTOR DIVISION • MILWAUKEE 1, U. S. A.

one of these C-E standard boilers is....

DESIGNED FOR YOUR PLANT

If your steam needs range between 4,000 and 120,000 pounds per hour, one of these versatile C-E Boilers will give you economical, standout performance. For while they are standard in design (which means lower first cost and proven performance), they're still *flexible* enough to be easily adapted to your exact requirements.

Chances are that one of the C-E standard boilers is the answer to your steam needs. But whatever they may be, C-E can fill them. For C-E Boilers are made in sizes and types for *any* capacity—for *any* pressure—*any* fuel or method of firing.

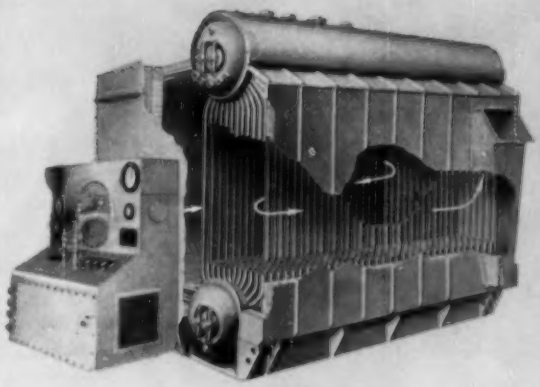


C-E Vertical Unit Boiler, Type VU-55

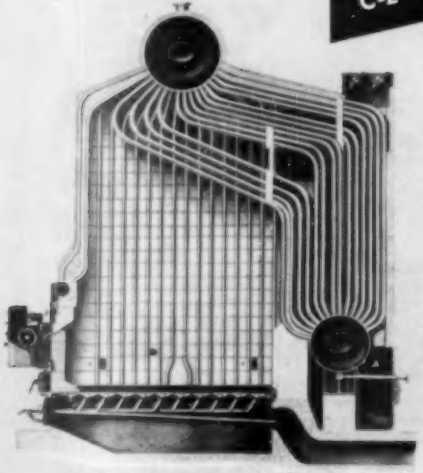
The VU-55 Boiler is available in six sizes ranging from 50,000 to 120,000 lb of steam per hr. It is designed for two pressure ranges—up to 250 psig and to 500 psig. These units are arranged for the application of superheater surface and heat recovery equipment if desired. VU-55 Boilers are designed for the pressure firing of oil or gaseous fuel and require no induced draft fan. They are equipped with tangential burners and tangent tube furnace walls to assure a level of performance which compares favorably with modern utility practice. The VU-55 Boiler is bottom supported requiring no supporting steel structure. The absence of exterior ductwork permits a smooth, streamlined exterior which is both attractive and practical.

C-E Package Boiler, Type VP

This completely shop-assembled boiler is available in fourteen sizes from 4,000 to 40,000 pounds of steam per hour ... for operating pressures up to 500 psi ... for pressure firing of liquid or gaseous fuels. The VP Boiler has more water-cooled area per cubic foot of furnace volume than any other boiler of its size and type. The large lower drum—30-inch diameter—permits a simple, symmetrical tube arrangement ... greater water storage capacity ... easy access for washing down or inspection. A centrifugal fan, which operates at low speed and is exceptionally quiet in operation, is standard equipment. The simple baffle arrangement results in low draft loss ... simple soot blowing ... no dead pockets ... high heat absorption. The VP is enclosed in a reinforced gastight, welded steel casing, and shipped completely assembled with firing equipment, fittings and forced draft fan. For foundation, it needs only a simple concrete slab.



C-E Vertical Unit Boiler, Type VU-10®



The VU-10 is available in nine sizes from 10,000 to 60,000 pounds of steam per hour ... for operating pressures up to 475 psi ... superheat to 200° F in 20,000-60,000 lb range ... for solid, liquid, or gaseous fuels. This boiler is a completely standardized design adaptable to many conditions. It is bottom-supported and needs no outside supporting steel. It operates efficiently over a wide range of output, and is easy to operate and to maintain. All parts are easily accessible for inspection. The VU-10 is a complete unit—boiler, furnace, setting, fuel-burning equipment, controls, forced draft, heat recovery equipment (if desired). Regardless of fuel, the same general cross-sectional arrangement of drums, convection bank and furnace wall cooling is used. Uniform design through each transverse section assures even water level in the drum and uniform expansion.

A C-E Industrial Boiler for Every Need — Combustion Boilers are available in many other 2-drum designs — for capacities up to 350,000 pounds of steam per hour — and to burn any commercially available fuel. All of these boilers can be designed for use with pressures up to 1375 psi and steam temperatures as high as 960 F—utilize any type of steam recovery equipment—fit difficult space conditions. Let us give you full details on the complete line of C-E Industrial Boilers, including the C-E LaMont Controlled Circulation Hot Water Boilers.

B-852

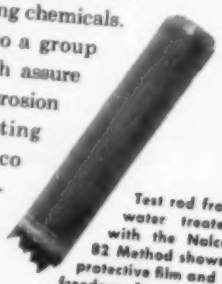
COMBUSTION ENGINEERING

Combustion Engineering Building, 200 Madison Avenue, New York 16, N. Y.

BOILERS, FUEL BURNING & RELATED EQUIPMENT; PULVERIZERS, AIR SEPARATORS & FLASH DRYING SYSTEMS; PRESSURE VESSELS; AUTOMATIC WATER HEATERS; SOIL PIPE

Forest of Facts on Nalco® RECIRCULATING WATER TREATMENT

NALCO Laboratories' continuous research program has gathered this forest of facts about protecting recirculating water systems. In the search for the most effective *and economical* formula, the metal rods shown have been rotated in all types of recirculating waters and treating chemicals. Results pointed the way to a group of Nalco Treatments which assure users against scale and corrosion in virtually any recirculating waters. For details on Nalco Treatment to fit your particular system, call your Nalco Representative, or write direct.



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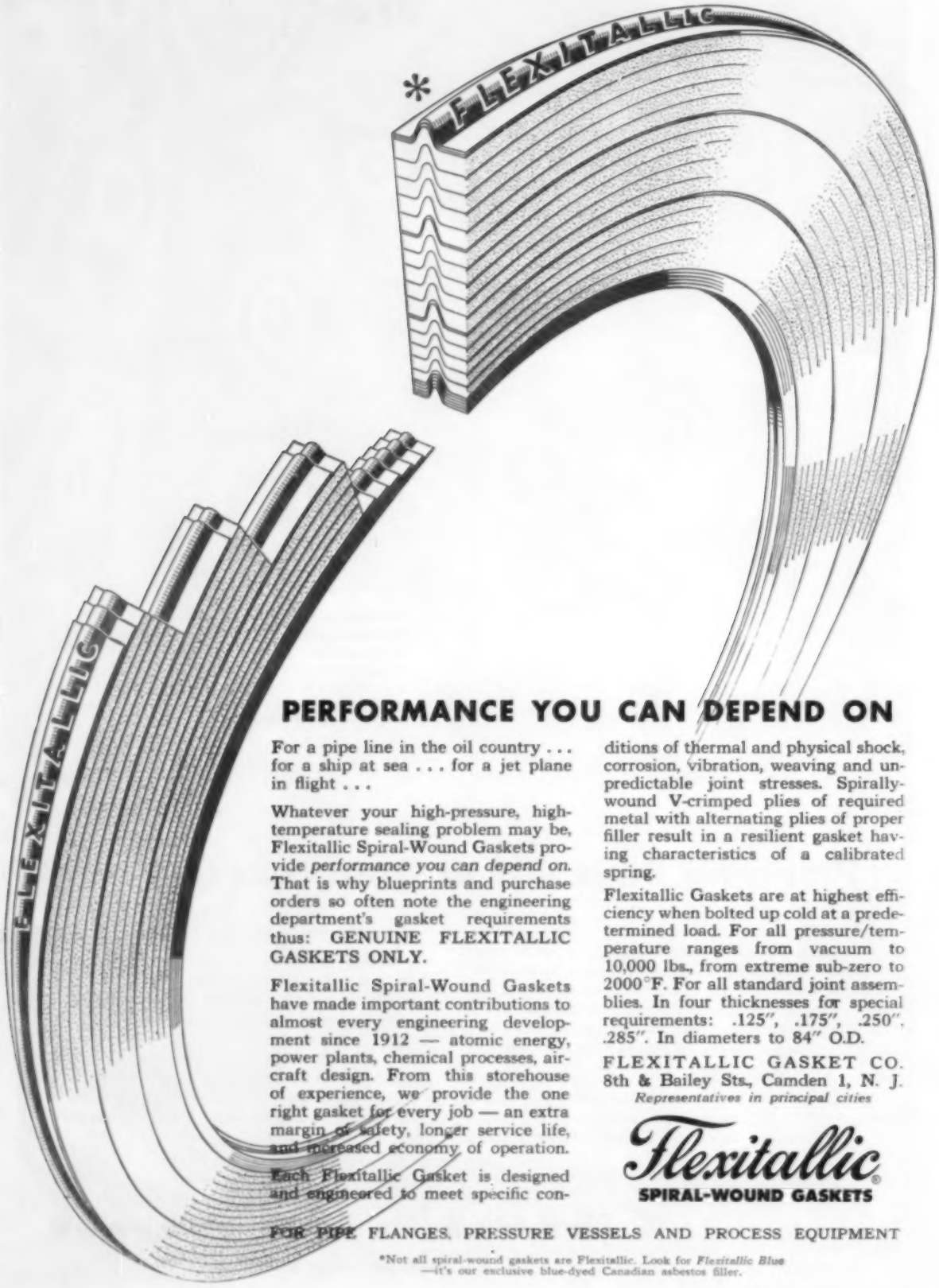

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Editorials

Evaluating Engineering Education

Progressive business organizations periodically evaluate major products in terms of market potential, economy of production and soundness of design. In carrying out this review function, industrial management is influenced by the desires and needs of customers as well as by the engineering skills of both its designers and its production specialists.

Something analogous to this also takes place in engineering education. The American Society for Engineering Education is the agency that conducts the periodic review, a practice that it has followed since its founding in 1893. At the recent ASEE Annual Meeting held at Pennsylvania State University, a 46-member committee under the chairmanship of Dr. L. E. Grinter, Dean of the Graduate School at the University of Florida, presented a searching and significant report based upon an intensive three-year study of engineering education. Much of the material is of general interest to practicing engineers because it foretells trends in engineering. Those specializing in power plant design and operation can likewise profit from reading the committee report, excerpts from which are presented elsewhere in this issue.

The basic thesis of the current evaluation—and this may be an oversimplification—is that engineers educated in the future must spend less of their college time in studying details of engineering practice and spend more in becoming thoroughly grounded in understanding the basic sciences, engineering sciences and relevant subject matter in liberal arts. This means, in effect, less time on power plant design and more on such subjects as modern physics, thermodynamics, report writing and engineering economy. Those who have feelings of regret that the engineering graduate of the future may be less capable of becoming immediately useful in designing power plants or power plant equipment should recall developments of the past decade and attempt to answer these questions:

Which has changed more rapidly, specific techniques of power plant design or principles of engineering thermodynamics?

Considering the impact of nuclear energy upon the power field, is it more advantageous to spend equivalent educational time in studying modern physics or learning how to test power plant components?

Which can more readily be acquired through industrial experience, production and operation know-how, or analytical techniques pertaining to stress and flow conditions?

Answers to these hypothetical queries delineate two philosophies of engineering education. The one advocates education of graduates whose knowledge of contemporary engineering practice is such that they may be of immediate use to an employer in the fields in which they have specialized. The other philosophy recognizes that technology is growing so rapidly that knowledge of fundamental science, supplemented by industrial training in specific applied technical practices, offers the most direct route to professional growth and engineering accomplishment.

Obviously it is the latter philosophy that guided the ASEE Committee on Evaluation of Engineering Education. Their evaluation merits widespread attention on the part of engineers throughout industry, government and education.

Economic Design and Selection of Cooling Towers*—I

By GEOFFREY F. KENNEDY, M.A., and P. H. MARGEN, B.Sc., (Eng.)‡

The present article, first of two, shows how an economic compromise can be found between packing shapes giving excessive friction and those giving insufficient heat transfer, and discusses the general method of economic packing and cooling tower design to a given performance specification.

COOLING tower technology in the U.S.A. and in Britain differ in several important aspects. Whereas the reinforced concrete type of tower illustrated on Fig. 1a is used in most large British cooling tower installations, the mechanical draught type tower shown by Fig. 1b is the most popular type in the U.S.A. This has led to the use of different forms of cooling tower performance equations and charts in the two Countries, though a generalized form applicable to both types has now been formulated (1).[1] American firms often favor packings of type i or ii on Fig. 2, whereas British firms have made wide use of packings iii to vi.

Regarding experimental work, the tendency in the U. S. has been to concentrate on the determination of heat transfer coefficients (3, 4, 5) whereas British experimenters (6, 7, 8) have laid stress on the joint determination of heat transfer and friction properties of the packings because the heat transfer factor in itself was not considered to be a sufficient indication of the merit of the packing. Indeed the correlation of friction and heat transfer data by Margen (1) suggests that it is easy to obtain high heat transfer factors at the expense of high friction factors by selecting a packing leading to violent eddy formation, and that designers should therefore seek an economic compromise between packing shapes giving excessive friction and those giving insufficient heat transfer.

Performance

In reference (1) the following performance equations are derived from the now generally accepted "enthalpy method" first proposed by Merkel (9).

Mechanical draught tower: $h_m'' - h_1 = Cy_M q p^{-1/4}$ (1a)

Natural draught tower: $h_m'' - h_1 = Cy_N q^{2/3} H^{-1/4}$ (1b)

where:

$$C = (F + fs)^{1/4}(1/sk + 1/2) \qquad (2)$$

The left-hand side of equations (1a) and (1b) represents the difference in enthalpy between saturated air at

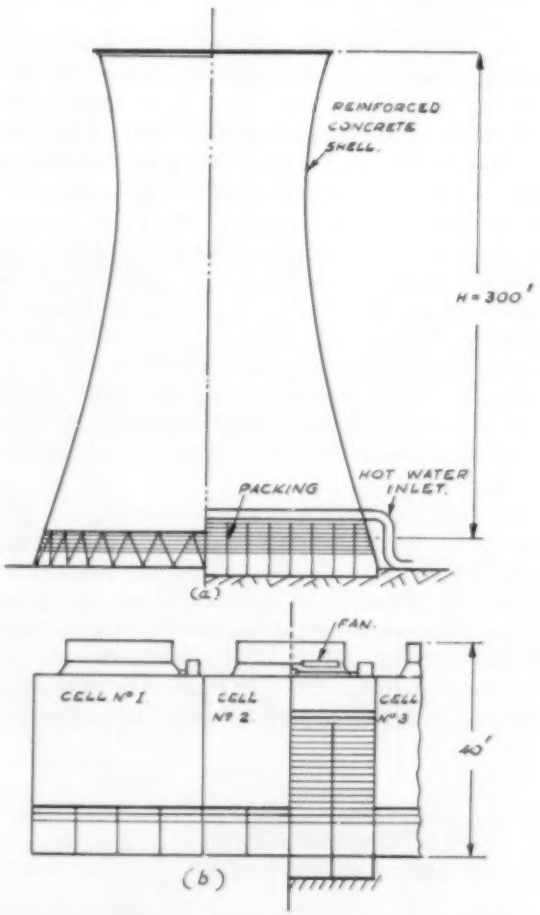


Fig. 1—Common types of cooling tower

(a) Natural draught. (b) Mechanical (induced) draught.

* In preparing this article the authors have made use of information and some of the diagrams contained in the papers cited in references (1) and (2), which were published in the Proceedings of the Institution of Electrical Engineers, Part A, Number 3, Volume 102, June 1955.

† Kennedy & Donkin, Consulting Engineers, London.

‡ Formerly with Kennedy & Donkin, London.

[1] Numbers in parentheses refer to Bibliography at the back of the article.

the algebraic mean circulating water temperature, θ_m, and the tower inlet air which is at the wet bulb temperature t_{w1}. It can be found for specified values of θ_m and t_{w1} from Fig. 3.

The right hand side of equations (1a) and (1b) contains the heat loading, q, of the tower; the effective fan power, p, or chimney height, H; the atmospheric factors y_M or y_N; and the performance coefficient, C, which was first proposed by Chilton (11). This coefficient is an inverse measure of the capability of the tower per unit horizontal area, high values of the coefficient denoting low capability, i.e. high water temperatures for a given duty. As shown by equation (2), this performance coefficient is a function of the packing and shell constants only, i.e. the shell resistance, F, the packing surface, s, and the packing friction and heat transfer numbers, f and k. It may thus be used to investigate the net effect of any change in the packing or shell design on the tower performance.

It should be noted that equations (1a) and (1b) are based on an approximate integration of the basic heat transfer equation $\delta q = kG(h'' - h)\delta s$, and involve errors of the magnitude illustrated by Fig. 4 relative to the accurate integration. These errors are acceptably small over the range of conditions met in most practical applications.

A method involving an accurate integration and carried out with the aid of a large book of graphs has been described by Lichtenstein (4) in the U.S.A., but cannot be applied to natural draught tower calculations without the aid of supplementary charts and laborious trial methods.

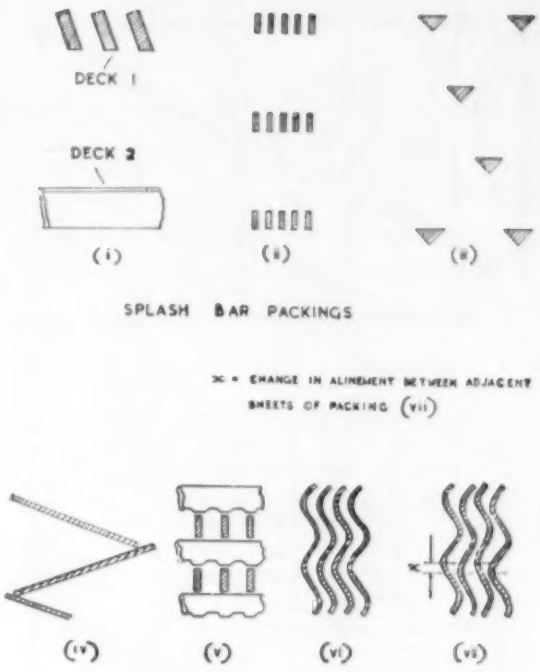


Fig. 2—Cooling tower packings

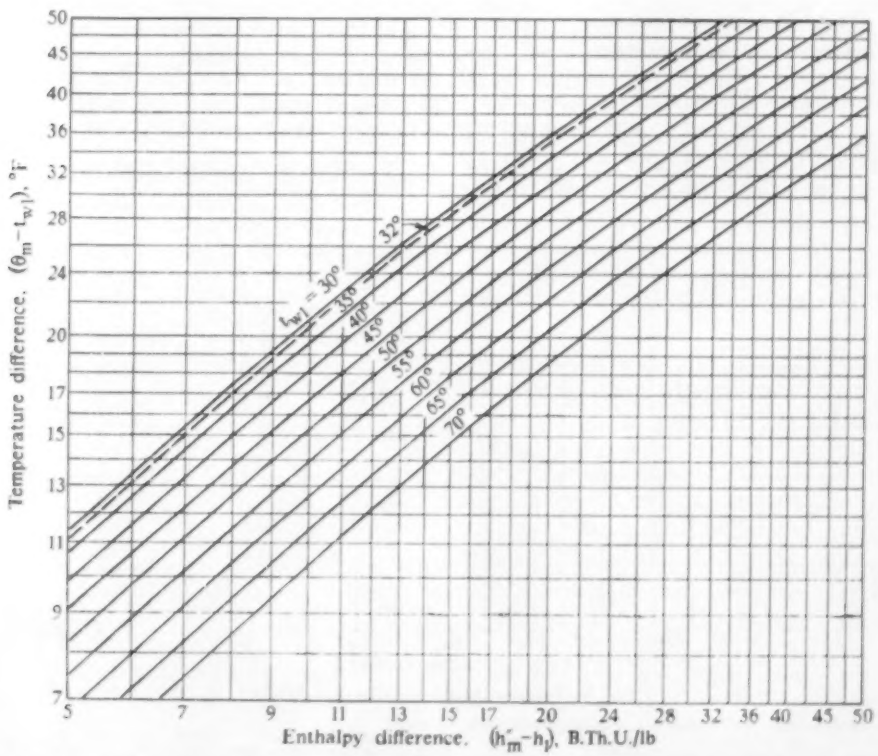
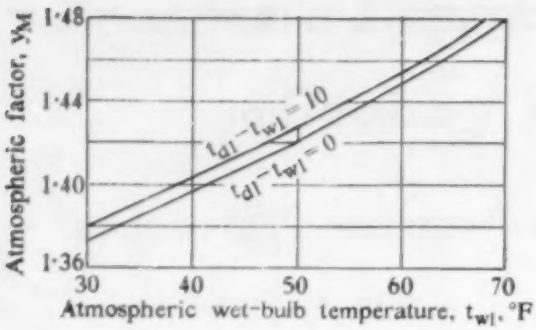
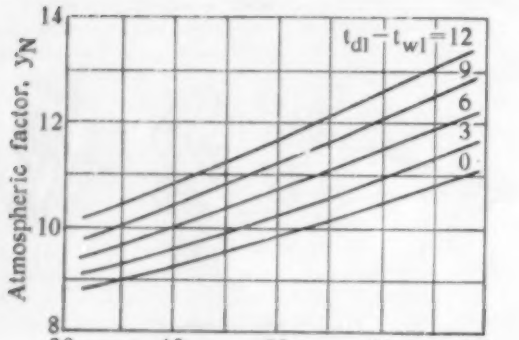


Fig. 3—Relation between temperatures and enthalpy difference. Plotted from reference 10



(*a*)



(*b*)

Fig. 4—Atmospheric factors

(*a*) Mechanical draught. (*b*) Natural draught.

Optimum Friction Factor

It is known that a change in the geometric shape of a packing which tends to produce greater eddy turbulence of the fluid increases both the friction and heat transfer numbers. Hence one might expect f and k to be correlated by an equation of the form,

$$f = Bk^c \qquad (3)$$

If that is the case, then for given values of the experimental constants B and c, and given values of the packing surfaces, s, and shell resistance, F, it is possible to calculate from equation (2) which value of the friction number f will give the lowest performance coefficient, i.e. the highest tower capability. This value of the friction number represents both the optimum and economic solution, since the geometric shape of the packing can usually be changed without affecting the packing cost per unit surface. By changing the alignment of corrugated sheets, the moderate friction and heat transfer number packing (vi) on Fig. 2 is, for instance, changed into the high friction and high heat transfer number packing (vii), Fig. 5 shows the heat transfer numbers of various film type packings (i.e. packings which do not promote drop surface) and heat exchangers plotted against the friction numbers, and suggests that the data are roughly correlated by the broken line over the range of interest. That line has the equation,

$$250\,f = (250\,k)^3 \qquad (3a)$$

Fig. 6 shows a chart prepared to give the optimum values of f and k for packings conforming to the above correlation. If the specified packing surface, s, and the specified shell resistance, F, are marked off on the diagram, then the optimum values of the friction and heat transfer numbers and the corresponding value of the performance coefficient may be read off the chart.

If the ratio of the annual cost z_s, of providing one sq ft of packing surface to the annual cost, z_A of providing one sq ft of horizontal tower area[2] is known, then Fig. 6 may be used also to determine the economic value of the packing surface, s, for a given shell resistance, using the five step procedure illustrated on Table 1. This procedure gives also the economic values of the effective fan

[2] This comprises the annual investment and maintenance costs for the tower foundations, shell, roof, water distribution system and eliminators, and for part of the fan motor set and control gear.

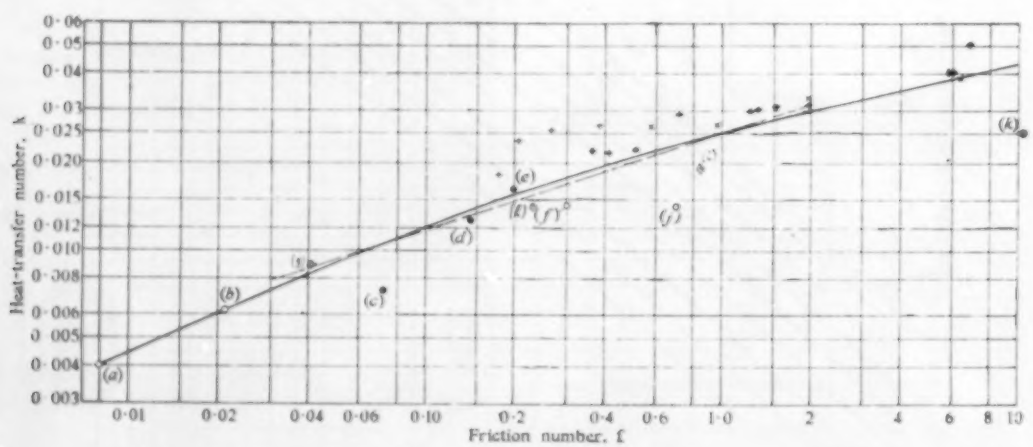


Fig. 5—Friction/heat-transfer correlation

———Law suggested by data. – – – – Linear approximation over range of interest.

Key to points (See ref. 1 for further particulars) (*a*) & (*b*) Calculated[1] from Reynold's analogy for $R_e = 10{,}000$. (*c*): Tests on packing made of vertical spaced laths.[8] (*d*), (*e*), (*f*): Tests on grid type packings.[5, 6] (*g*), (*h*), (*i*): Tests on corrugated sheet packings.[13] (*j*) & (*k*) Tests on stacked rings[6] and random rings, respectively.

× + ⊕ ⋕ Calculated from empirical formulas cited in McAdams[12] for air flow perpendicular to banks of tubes at various spacings.

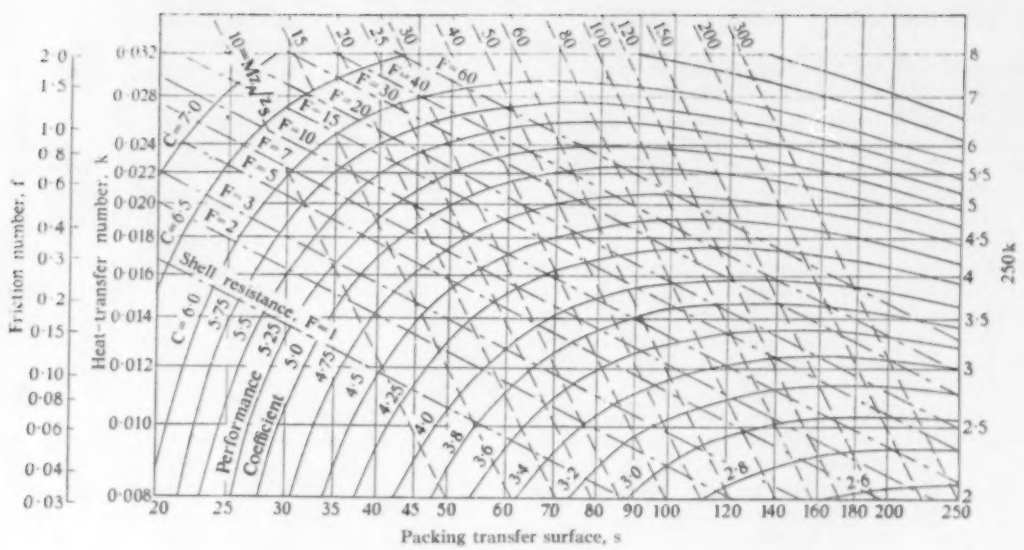


Fig. 6—Chart for economic tower design

Plotted from formulas: $Mz_A/z_s = ks^2/2$; $F = 31,250k^4s^2$; $C = 15.8\,(ks^{1/3} + 2s^{-1/3})^4/s$.

power, p, or chimney height, H, with the aid of the following three supplementary equations:

$$\text{Economic } p = \eta_F(z_A + z_s s)/2z_E \tag{4}$$

$$\text{Economic } H = (z_A + z_s s)/2z_H \tag{5}$$

$$M = \frac{1 - S'Wz_w/a_w z_A}{1 + wz_w/a_w z_s} \tag{6}$$

= Factor having values of about 0.75 for most film type packings.

In these expressions, z_F and z_w represent the annual cost incurred by increasing the power input rating of the fans and pumps respectively, by 1 ft-lb/sec, and z_H is the annual cost of increasing the chimney height by one ft, expressed per sq ft of horizontal tower area.

The entire design procedure requires a knowledge of only three main design constants, namely the shell resistance, F, and the cost ratios z_A/z_s and z_F/z_s (or z_H/z_s with natural draught). The fan and pump efficiencies, η_F and η_w, and the surface/volume ratio, a, of the packing have only a secondary effect on the solution for film type packings.

Inspection of Fig. 6 reveals that low values of the shell resistance, F, and high values of the Area/packing surface cost ratio, z_A/z_s, tend to make packings with low friction numbers, low heat transfer numbers and large surfaces per unit ground area economic. A practical example of such a design is a small mechanical draught tower situated on a very expensive site, so that z_A/z_s may be as high as 100 and the shell resistance as low as 8 velocity heads. Then, for $M = 0.72$, the economic

TABLE I—EXAMPLES OF ECONOMIC DESIGN

Item	Symbol	Amount		
Specified duty				
(a) Heat quantity, Btu/sec	$Q = qA$	300,000		
(b) Water temperatures, °F	θ_1, θ_2	$\theta_1 = 85$, $\theta_2 = 69$	$(\theta_m = 77)$	
(c) Atmospheric temperatures, °F	$t_{w1}\ t_{d1}$	$t_{w1} = 49$	$t_{d1} = 52$	
		Mechanical draught	Natural draught—Type I*	Natural draught—Type II*
Design data				
(a) Shell resistance	F	13	25	16
(b) Fan-set efficiency	η_F	0.6	—	—
(c) Area cost ratio	z_A/z_s	59	57	73
(d) Fan-power cost ratio, sec/ft-lb	z_F/z_s	4.80	—	—
(e) Pumping-power cost ratio, sec/ft-lb	z_w/z_s	4.36	4.36	4.36
(f) Chimney cost ratio,† ft^{-1}	z_H/z_s	—	0.23	0.29
Design				
Step 1. Estimate the factor M	M	0.71	0.79	0.76
Step 2. Read from Fig. 6, for given F and Mz_A/z_s				
(a) Heat-transfer number	k	0.0170	0.0207	0.0162
(b) Friction number	f	0.310	0.56	0.265
(c) Packing surface	s	70	66	82
(d) Performance coefficient	C	4.35	4.85	4.17
Step 3. Obtain from equations (4) and (5)				
(a) Air power (ft-lb)/sec ft	p	8.05	—	—
(b) Chimney height, ft	H	—	270	270
Step 4. Obtain from Figs. 1 and 2 and equation (5), respectively	y_M, y_N	1.42	10.22	10.22
(a) Atmospheric factors				
(b) Enthalpy difference, Btu/lb	$h_m^* - h_1$	21.0	21.0	21.0
(c) Heat loading, Btu/sec-ft	q	6.82	4.50	5.66
(d) Horizontal area (Q/q), ft^2	A	44,000	66,600	53,000
Step 5. Check M from equation (6)	M	0.70	0.80	0.75

* Types I and II represent towers with and without water-collecting troughs respectively.

† This actually varies with height and diameters.

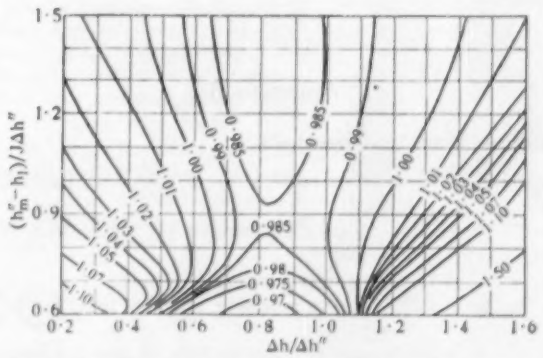


Fig. 7—Distribution factor for contra-flow cooling tower.

Drawn for $h_1 = 11$ Btu/lb, $\Delta\theta = 18°F$. For lower values of h_1 and $\Delta\theta$, J is slightly greater than shown by chart; for higher values of h_1 and $\Delta\theta$, J is slightly smaller.

packing particulars are $s = 108$, $k = 0.0121$ and $f = 0.112$.

An example of the opposite tendency is provided by a large natural draught cooling tower, which might have a z_A/z_s ratio of about 57 and a shell resistance of 25 velocity heads, giving the economic packing particulars $s = 66$, $k = 0.0207$, $f = 0.56$ shown in Table I. The range of variation in the economic friction factors is thus nearly 0.1 to 0.6, and several packings should be developed to cover this range adequately.

The above discussion applies to film type packings satisfying the friction/heat transfer correlation, equation (3a). One might expect that certain types of film packings will not satisfy this relation accurately, and if the relevant experimental data are available to determine the values of the constants B and c for these packings in equation (3), a new chart similar to Fig. 6 may be constructed for the new values of these constants, using equations given in reference 1. A design procedure similar to that described above may then be applied with the aid of the new chart.

In the case of splash bar type packings, i.e. packings which have a considerable proportion of the transfer surface in the form of water drops, the procedure can be laborious because the values of k and f vary with the water rate, w. Shortened design procedures can be evolved for these packings, but a description of these is outside the scope of the present article.

Conclusions on Design

The above examples indicate that the representation of the performance of a cooling tower by a single coefficient, C, greatly facilitates the designer's task. It has been shown how that coefficient can be used to determine the economic compromise between the friction and heat transfer properties of the packing. For precise results the work should be supported by an experimental k/f correlation for the particular type of packing used, but for many purposes the approximate correlation, equation (3a) on which the design chart, Fig. 6, is based gives results of sufficient accuracy. This design chart makes it possible to determine the economic values of the packing constants, packing surface and performance coefficient practically by inspection, and with its aid economic tower designs can be completed rapidly. The examples suggest that each cooling tower maker should develop several packings covering a range of friction numbers for different applications.

Appendix A

List of Principal Symbols

A = Mean horizontal area of tower at packing level, ft².

a = Area of packing surface per cubic foot of space, ft⁻¹.

C = Cooling-tower performance coefficient.

η_w, η_F = Efficiency of pumping and fan sets, respectively.

F = Resistance of tower shell to air flow, (= head loss in feet divided by $G_t^2/2g\rho^2$).

f = Friction number of packing (= head loss in feet divided by $sG^2/2g\rho^2$).

G = Dry air-mass flow rate per unit A, lb/sec-ft.

g = Gravitational acceleration, ft/sec².

H = Height of natural-draught chimney above mean packing level, ft.

h = Mean enthalpy of air in the main current, Btu per pound of dry air.

h'' = Enthalpy of saturated air at the water temperature Btu per pound of dry air.

k = Heat-transfer number of packing (= mass transfer coefficient/G).

M = Factor defined by equation (6).

p = Air power expended per unit A, ft-lb/sec-ft².

q = Heat loading of tower pure unit A, Btu/sec-ft².

q_e = Heat loading of turbine exhaust, Btu/sec-ft².

r = Ratio: (Total air weight)/(Dry air weight).

s = Packing surface per unit A.

t = Steam temperature corresponding to condenser vacuum, °F.

t_w, t_d = Wet-and-dry-bulb air temperatures, °F.

w = Water-flow rate per unit A, lb/sec-ft².

y_M, y_N = Atmospheric factors shown on Fig. 4.

z_s, z_A, z_F, z_w, z_H = Cost factors relating to packing surface, horizontal tower area, fan power, pumping power and chimney height, respectively, (units given in text).

ρ = Nominal density of air, pounds of dry air per cubic foot of air-vapor mixture.

θ = Water temperature, °F.

Subscripts 1, 2 and m are used to designate, respectively, values at the air inlet, air exit and point of 50 per cent heat release in the packing (i.e.) (at the algebraic mean water temperature).

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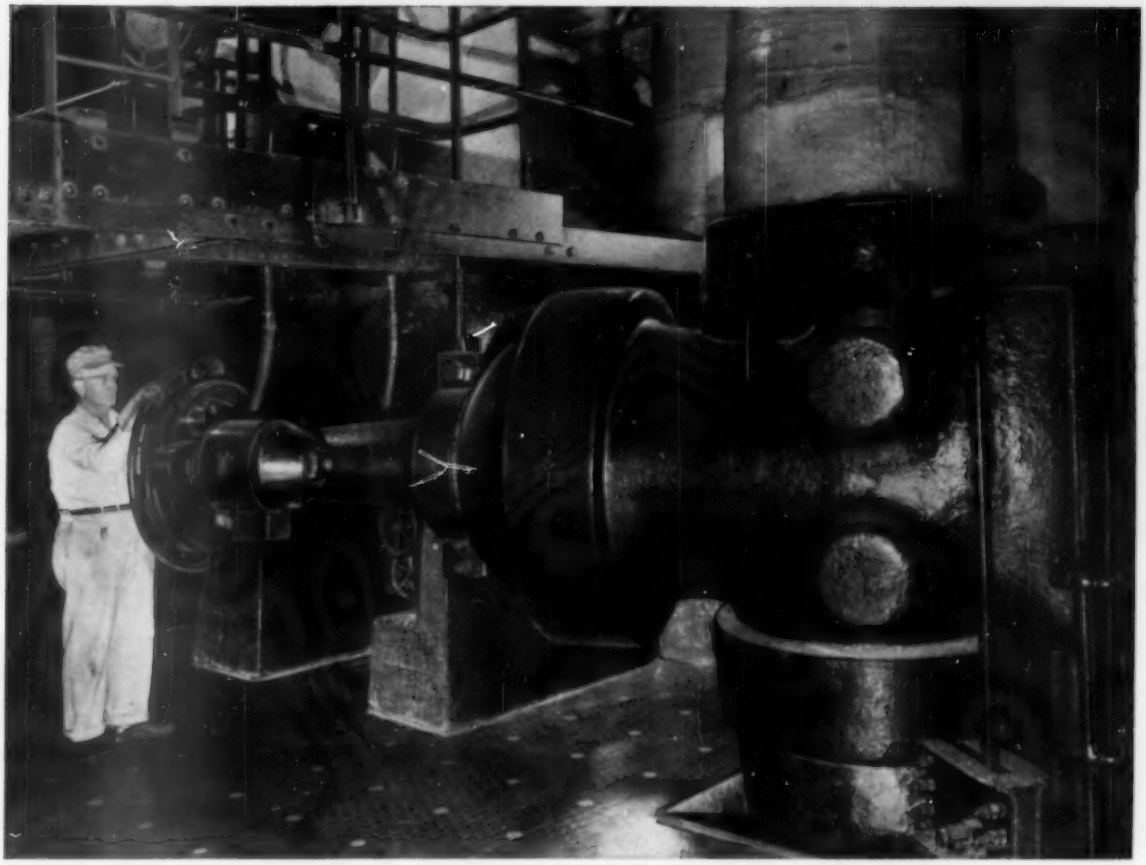

Dividends from this Crane valve over 30 years... 6¾ billion kilowatt-hours

Over thirty years ago, this 30-inch Crane steel gate valve was put in service at Commonwealth Edison's Crawford Station in Chicago.

As of May, 1955, unit No. 1 on which this motor-operated valve is installed, had been in operation more than 150,000 hours. Total power output generated with this valve in service was approximately 6,750,000,000 kilowatt-hours.

The valve is on reheat steam service with working conditions of 100 psi. at 700 degrees F. Never out of the line, and given but routine maintenance attention since installed in 1925, the valve's performance remains completely satisfactory.

Seating action is positive and tight; bonnet-joint and stem seal are tight; operation is smooth.

There is nothing special about this rising stem, cast carbon steel valve—nothing but its dependable Crane quality. Development of steel valve castings was pioneered by Crane; long life and low maintenance are deeply rooted characteristics of Crane valves.

In steel valves, as in other materials, the Crane line is most complete: gates, globes, angles, checks and stop-checks—bolted, Pressure-Seal, and Lip-Seal bonnet designs—screwed, flanged, or welding ends—sizes up to 24 in.—pressure classes up to 2500 psi.

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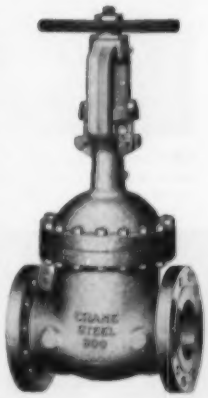

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Westinghouse Opens Atomic Parts Manufacturing Plant

First privately financed atomic equipment plant located on a 112-acre tract of land at Cheswick, Penna., about one mile northeast of the Allegheny Valley Interchange of the Pennsylvania Turnpike

Drafting department of 87,000-sq ft plant manufacturing canned motor-pumps in capacities to 17,000 gpm.

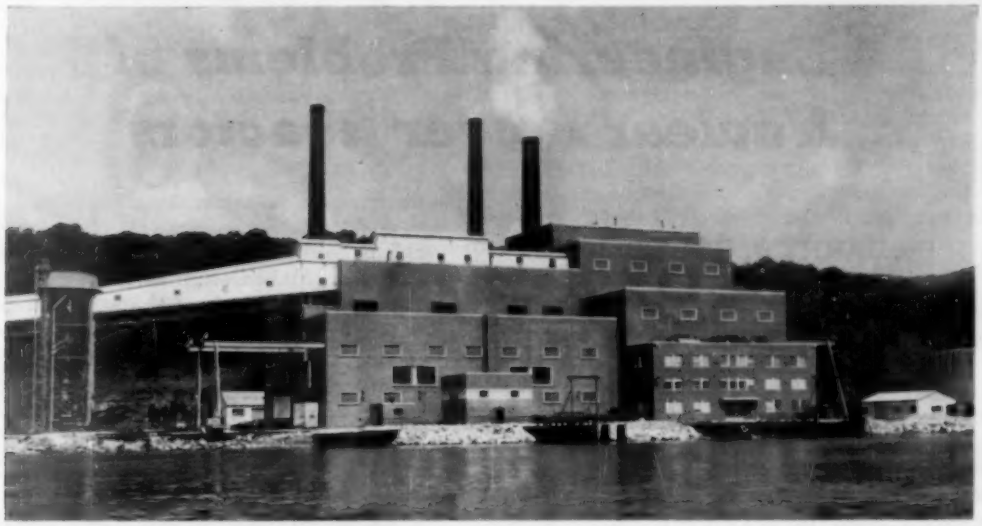
Boring mills, drill presses, lathes and other machinery are shown here in this interior plant view

Welding nickel alloy can to rotor end plate by shielded-arc method. Dye penetrant inspection follows

The highly polished finish on the thrust-bearing runner for a canned motor-pump has a mirror quality

Canned motor-pump on C-E controlled-circulation boiler at Possum Point Station of Virginia Electric & Power Co

Finish boring of the stainless steel volute of a canned motor-pump is a very precise process



Exterior view of Lovett Plant showing third unit of recently completed extension on right

Rockland Light and Power Company Doubles Electric Generating Capacity

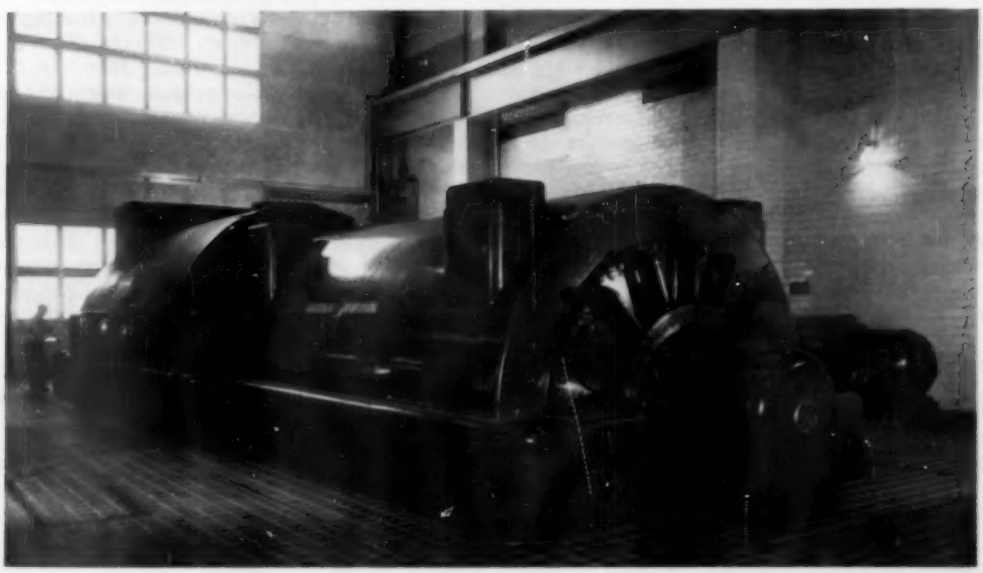
During the week of July 20, Rockland Light and Power Company, which has its headquarters at Nyack, New York, observed the activation of the third and largest electric generating unit at Lovett Plant located at Tomkins Cove on the Hudson River about 30 miles upstream from New York City. This section of the station, as were the other two, was designed and constructed by Burns and Roe, Inc., New York consulting engineers.

Steam is supplied by a Combustion Engineering radiant-reheat boiler operating at 1850 psig, 1050 F with reheat to 1000 F to a General Electric tandem-compound turbine generator having a capability of 70,000 kw. Eastern bituminous coal, oil or natural gas may be fired in the boiler which is equipped with vertically adjustable burners, bowl mills, economizer and tubular air heater.

An interesting feature of the plant, as depicted on the cover of this issue, is a turbine-room backdrop formed by the Maritime Administration Reserve Fleet anchored nearby on the Hudson River. Rockland Light and Power Company supplies power for cathodic protection of this important segment of the reserve fleet.

In proclaiming Lovett Plant Week, Charles L. Hulswit, president of Rockland Light and Power Company, stated that Lovett Plant reflects the accomplishments of an eight-year, $25,000,000 construction project which is intended to accommodate the increased power requirements of its 70,000 customers and to insure adequate supplies of electricity to meet future growth.

General Electric reheat turbine-generator having a capability of 70,000 kw



Engineering Problems of Nuclear Power Reactors*

By HARRY J. BOLWELL

Combustion Engineering, Inc.

The field of nuclear power is in a unique position in that engineering development is lagging the work of the research groups to an extent that the entire nuclear program has suffered. In considering the problems this condition raises the author limits himself to the general problems of heterogeneous reactors cooled by either water or liquid metal, since both types have been or are now being built. The Pressurized Water Reactor, as probably the most common design of nuclear power reactor to be built within the next five years, receives special emphasis.

THE first factor to consider in discussing the engineering problems of power reactors is the primary coolant and its effect on the equipment design. Since this discussion will be a non-nuclear one, differentiation will not be made between H_2O and D_2O in an aqueous system. Sodium will be considered as a typical coolant when examining a liquid metal system. Sodium has been commonly used and is representative of all liquid metal coolants.

The following requirements are common to all reactor coolants: 1. The coolant must be a good heat transfer medium. 2. The coolant must be amenable to maintaining high purity. 3. The coolant must cause little or no corrosion of the fuel elements or primary system equipment. 4. The coolant must be contained. A high degree of leak tightness is a requirement of any reactor system.

These requirements impose various problems on the engineer designing a water or sodium system.

Good Heat Transfer Medium

Water is one candidate for a primary coolant. It has a high heat capacity but it also has a high film drop. Briefly, a film develops on the heating element. This film impedes heat flowing from the heating element to the water coolant. Probably the most serious problem imposed by a water coolant is the critical temperature limitation of water. In order to obtain a high enough coolant outlet temperature to be practical, the system must be capable of containing high pressures. In early reactor designs even localized boiling was considered hazardous. More recently some localized boiling has not been considered detrimental. However reactors are still being designed so that the maximum core temperature is somewhat less than the primary coolant saturation temperature.

Sodium is a second possibility as a primary coolant. It has the advantages of virtually no film drop and a high boiling temperature. Sodium does react violently, however, with water. Special precautions are necessary to insure the primary coolant's being isolated from the steam system. In general, there are two ways of isolating the radioactive sodium. One would be to design a steam generator so that a second tube will incase the tube in which the sodium is flowing. The volume between the tubes might be filled with an inert gas. The water would be outside of the second tube. Thus, if sodium leakage did occur, the water could be protected by a secondary barrier. A second method would be to include an intermediate loop in the system. The radioactive sodium would transfer the heat in an intermediate heat exchanger to a less active fluid such as NaK. The NaK would then act as the heat-transferring agent in the steam generator.

Purity

No matter what the choice of primary coolant there can be no in-leakage of impurities in the primary coolant, and provision must be made for a high purity make-up system. The reasons for this requirement are obvious. It is imperative that the fuel elements be free from foreign deposits. Certain impurities will accelerate corrosion. Most impurities will become highly radioactive, and if deposited on other equipment in the system, such as pumps and valves, they can create sizable maintenance problems. Here is how impurities affect our primary coolant candidates, water and sodium.

High purity water enjoys the advantage of being achieved without too much difficulty. But, high purity water is a highly corrosive fluid. Therefore, the requirement of high purity in an aqueous system sets up a never-ending cycle. High purity causes corrosion. Corrosion requires a clean-up loop to maintain high purity. Water does have the advantage of being less radioactive than sodium. In general, pure water has only a seven-second half-life due to N^{16}. The impurities common to water, such as iron, nickel and manganese, do not have this advantage. For the most part, they become highly radioactive, have long half-lives, and must be removed. To sum up, in a water system a complete clean-up loop is necessary. The resultant purity must be two ppm maximum dissolved solids in a system.

The properties of sodium on the other hand, are such that the coolant becomes highly radioactive when it comes in contact with the nuclear core. Thus, the activity of the impurities in the coolant is not so important. One of the greatest problems affecting purity in a sodium system is the tendency of free oxygen to form sodium

* Presented before the ASME Semi-Annual Meeting, Boston, Mass., June 19-23, 1955.

oxide. It is undesirable to have a deposition of this material on the fuel elements and other equipment. Steps must be taken to remove this sodium oxide from the system and a method of removal is explained later.

Corrosion

As mentioned above, high purity water is very corrosive. Only zirconium, 300 series stainless steels and such metals as stellite are corrosion resistant, to the degree required. As yet no good corrosion inhibitor is available for a high temperature water system. Various techniques have been used to limit corrosion. It has been found necessary to maintain an excess of hydrogen in the system which can combine with and eliminate excess oxygen. In the Argonne National Laboratory, for example, a 400 series stainless steel rack and pinion was operated in water at 450 F with an excess of oxygen. After fifteen hours of operation the rack and pinion galled and seized. A second series of tests was run involving identical components operated in identical conditions with the exception that an excess of hydrogen was maintained in the system. The rack and pinion ran for five million cycles, and upon examination only a slight polishing of the gear teeth was noticeable.

A recent development, still in the laboratory stage, has been the use of the element technicium as a water corrosion inhibitor. This element, which is a fission product of uranium, was very effective at the lower temperatures below 400 F.

Preliminary tests have indicated that the addition of ammonia in a hot water system is helpful in reducing corrosion. Since only several ppm of ammonia are used, any activity from resultant free nitrogen is not harmful.

It was mentioned above that the sodium oxide tends to form in the sodium coolant system. In addition to its other undesirable qualities, this oxide is highly corrosive. A method has been developed to remove sodium oxide from the system. Inasmuch as the oxide freezes at a higher temperature than the sodium coolant cold traps can be incorporated in the system and the frozen sodium oxide can be intermittently removed. At temperatures above 1000 F, however, the sodium coolant itself becomes corrosive and hence the coolant temperature in a sodium system is usually maintained between 800 and 900 F.

Leakage Containment

The primary coolant pressure of a water system is usually from 1500 to 2000 psi. It has been the practice in earlier power reactor development to specify a zero leakage requirement of the primary coolant. There are certainly valid reasons for this requirement in a mobile reactor plant. It is felt, however, that this zero leakage philosophy should be revised when designing pressurized water systems for land-based power stations. For years central power stations have tolerated some nominal leakage in the system. It may well be that major cost reductions can be realized if nuclear power plant designers would follow the conventional power plant leakage requirements.

The problem still remains, even with some allowable leakage, of building equipment to withstand a pressure of 2000 psi. These problems will be illustrated in more detail later when the individual components are discussed.

A sodium system is designed to operate at much lower pressures, in the range of 100 to 300 psi. But the rigid leakage requirements which may be relaxed in the water system must be maintained in the sodium system. In addition to the requirements of structural integrity, sodium system components must have high metallurgical requirements because radioactive sodium can and does penetrate inclusions on the surface of the components. Such a penetration would be very difficult to remove, and it could cause a violent reaction. The sodium coolant has a 14.8-hour half-life and certain isotopes such as Na_{24} are extremely active. Leakage of this isotope would be very hazardous. In designing a sodium system, therefore, the engineer must still consider zero leakage to be a firm requirement.

The reactor moderator represents still another factor to consider when a comparison is made between a water and sodium coolant. Its function is to slow down the rate of travel of the emitted neutrons so that their availability for capture will be greater. In a thermal reactor, for example, the neutrons need to be slowed down quite appreciably. They move somewhat faster in an intermediate reactor and a good deal faster in a fast reactor. In line with this requirement water has displayed the property of being both a coolant and a moderator which makes it almost unique in this property. On the other hand sodium coolants used mostly in intermediate and fast reactors, require a moderator, such as beryllium, in the case of an intermediate reactor. This necessity of a special moderator certainly has an effect on an economic comparison of the two types.

Reactor System Equipment

A high fuel density is required in reactor engineering because of the high fuel cost and fuel element fabrication and reprocessing costs. The table below gives an example of the comparative heat fluxes in a coal fired boiler to those in a reactor core.

Coal Fired Boilers. Maximum in burner area, 100,000 Btu/hr ft^2 to 200,000 Btu/hr ft^2; average, 35,000 Btu/hr ft^2 to 50,000 Btu/hr ft^2.

Reactor Core. Maximum core center line, 150,000 Btu/hr ft^2 to 300,000 Btu/hr ft^2; average, 50,000 Btu/hr ft^2 to 100,000 Btu/hr ft^2.

Fuel Elements

The fuel elements used in an aqueous system must be clad with a non-corroding material. If it were decided to use an unclad uranium fuel element in a water system the corrosion of the uranium would be measured by the yard. The corrosion problem, however, when sodium contacts uranium is not as serious. As a matter of fact in future reactor designs, fuel element cladding may not be required with a sodium coolant. The necessity of cladding the aqueous system fuel elements imposes a fabrication problem on the reactor designer and builder. The materials to be clad, such as uranium and plutonium, as well as certain cladding materials, such as zirconium, are relatively new materials, and a backlog of fabrication experience is not available. In order to illustrate the fabrication problems of fuel elements it may be well to go through a typical fabrication procedure of a hypothetical fuel element. The fuel element may be an assembly of fuel plates.

The first step then, is the fabrication of the fuel plates.

The start is a thin, rectangular sheet or slab of uranium. This slab of uranium may then be placed between two oversized slabs of cladding material, such as zirconium. In effect we now have a sandwich, the uranium being the meat of the sandwich, which can now be rolled and the outside of the cladding welded or brazed to render the plate leak-proof. During reactor operation the fuel will generate highly radioactive fission products in the form of gases and the fuel element cladding must contain these fission products.

A fuel assembly may contain several fuel plates. These plates can fit into two grooved side sections, machined so that the spacing between the plates will be consistent. The bottom and top of the assembly is left open so that the coolant will flow through the spaces between the plates. It is extremely important that close tolerances be held on the spacing grooves aligning the fuel plates. If the spacing is not consistent, the predetermined mass of coolant will not flow by a certain fuel plate and that fuel plate, therefore, could overheat and possibly melt the cladding. The gaseous fission products would then be carried throughout the system and would be deposited on the primary loop components.

There are other types of well-known fuel elements, such as rods and cans. The fabrication processes are similar in that a consistent cladding and spacing is absolutely necessary.

Reactor Core Components

In addition to fuel elements a typical reactor core would contain the following components:

1. Flow guides to insure an equal flow distribution throughout the core.
2. Control rods to control the reactor.
3. Bearings for these rods as they move.
4. A thermal shield to alleviate thermal stress in the reactor vessel.
5. A hold down device to prevent the fuel elements from moving or chattering under high flow conditions.

All of the above components must be fabricated from a special non-corrosive material. Since physical positioning must be maintained with extreme accuracy in a reactor core, all the components must be fabricated to close tolerances. The rod bearings cannot be lubricated and yet the rods must have complete freedom of motion. The hold down device must be capable of giving core rigidity and yet must be a quick opening device for ease of core reloading. These problems are typical in that they are relatively complex and interrelated.

Control Systems

A general philosophy of control is to use as a control point a fixed reactor outlet temperature. Fig. 1 illustrates the usual double loop used in a pressurized water system. If an increased demand appears at the turbine shaft, the turbine throttle opens, the pressure in the line to the turbine falls, more heat is transferred from the primary loop to the secondary steam system, and eventually the temperature out of the reactor, assuming no increase in the release of heat generation there, will fall. This creates an error signal to the control system, which causes the power level of the reactor to be raised to meet

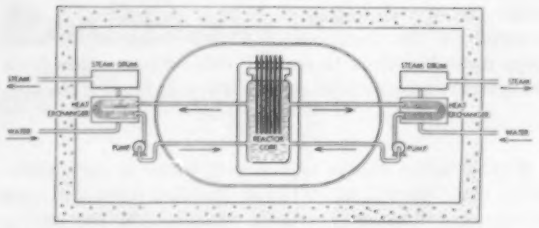


Fig. 1—Arrangement of double loop in pressurized water system

the increased demand. A decrease in power demand results in the reverse condition.

The reactor power level can be controlled by the insertion or removal of control rods. The rods must be made of a material that is, in effect, poisonous to the nuclear reaction. Three typical materials that might be used would be cadmium, boron, or hafnium. Since cadmium also corrodes in water, it too must be clad. It has the advantage of welding easily, but it is not usually used in a sodium system since it melts at the higher operating temperatures. Boron is brittle and is used only in such forms as boron steel or boron carbide. Hafnium is expensive but does have good corrosion resistance, good physical properties, and welds easily.

As mentioned above, the motion of the rods will be controlled by the plant output requirements. There are emergency conditions which will override the normal control and cause an extremely fast insertion of all rods. This fast insertion is commonly called a scram. There may be any number of events, depending upon reactor design, which would cause a scram. An extremely fast rise of the primary coolant outlet temperature might be such an event or a rise in the radiation level as detected by appropriate nuclear instrumentation would most certainly cause a scram.

It is sometimes required to add an extension of stainless steel to a control rod, thus making it longer and more unwieldy. When a control rod is withdrawn from the reactor core, a void will be left in the core. If water were to fill this void, neutron flux peaking would result in this area. The extension, therefore, would fill the void with steel rather than with water but it would impose problems to the designer of the flow guide since the guides must be positioned so that the control rod extension will have clearance when the rods are entirely in the reactor core.

When control rods are used they must be driven by a control rod drive mechanism. There are four general requirements of a control rod drive mechanism:

1. The mechanism must induce reciprocating or rotary motion.
2. The mechanism must be capable of fineness in control. In effect, when the operator asks the rod to stop moving, the rod must stop moving with as little coasting as possible.
3. The mechanism must indicate the position of the rod to the operator at all times.
4. The mechanism must be capable of reinserting (scramming) the rod into the reactor core with an acceleration of approximately 1 G.

The illustration, Fig. 2, shows a simplified drive mechanism. It will be noticed that the mechanism employs a

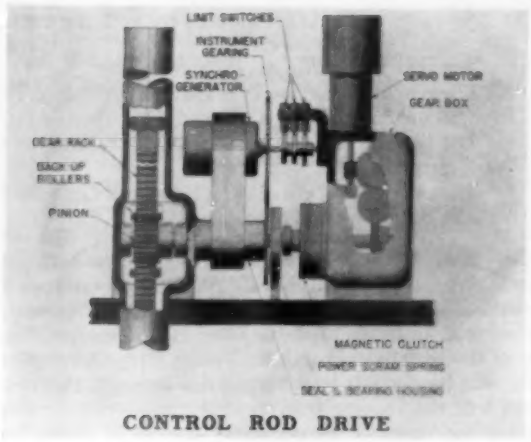


Fig. 2—Simplified drive mechanism

rotary shaft seal. In using such a seal some leakage must be expected. If this leakage can be collected, it is felt that such a mechanism would be acceptable from a plant operation standpoint, and certainly would be more economical than most drive mechanisms now in use.

As illustrated, the drive mechanism consists of a low-inertia driving motor, a reduction gear train, a quick releasing magnetic clutch, a scram spring, a simplified indication system, the rotary seal, a rack and pinion, and a rod latching device.

The low-inertia motor will be specified so as to achieve the requirement of fineness of control as well as inducing rod motion. The gear train is necessary to give the required slowness of rod travel. The magnetic clutch will quickly release the rod upon power failure or electronic impulse. The spring will then drive the rod into the core with the required acceleration. The instrumentation system consists of a gear-driven synchro-generator to fulfill the requirement of position indication and adequate limit switches to control rod travel.

The latch mechanism offers a complex problem. This mechanism must be the connection between the rod and the rack. It must do more than that, however. During reactor refueling the control rods must remain in the reactor core while the fuel elements are being replaced. The latch must be capable of being remotely disengaged from the rod so that refueling can be accomplished.

The rod mechanism described above typifies an economical device that may be used in an aqueous system. There have been many other such devices designed for both sodium and water reactors. Some of these devices are designed with a zero leakage requirement. Most of the mechanism, therefore, must be submerged in the coolant. The corrosion and lubrication problems alone impose stringent design requirements and do not aid in any way in reducing plant cost.

There is a factor to be considered which is typical to a water reactor and which greatly eases the problem of reactor control. This factor is known as a negative temperature coefficient. In effect, as the coolant temperature rises, the effective neutron flux goes down. A very oversimplified explanation of this is that as the liquid expands or becomes less dense, all the nuclei of the coolant are pushed further apart, leaving more gaps through which neutrons may escape without causing fission.

Reactor Vessels

When designing a nuclear power plant the physicist desires the largest possible core volume in order to obtain a maximum power output. The design engineer again must be the one to indicate the limiting factor in core sizing, especially in an aqueous system. The reactor vessel now being constructed for the Pressurized Water Reactor to be installed in Shippingport, Pennsylvania, will be one of the largest vessels ever built to withstand the required operating pressure. The design pressure of the vessel illustrated in Fig. 3 is 2500 psi; the design temperature is 600 F. The inside diameter of the vessel is approximately nine feet. The vessel wall thickness is approximately eight and one-half inches. Obtaining high quality plate for the vessel wall is very difficult. At this time it is felt that this plate thickness is maximum, since larger plates of high quality cannot, as yet, be guaranteed by the steel mills. Therefore we have reached the limit of vessel diameter for a 2500 psi type pressure. Should the nuclear physicist design a larger core the design engineer must consider a multiplicity of vessels or a hitherto undiscovered vessel design.

In order to install and possibly reload the reactor, this extremely large vessel must be equipped with a removable head. The force required to hold down a head of nine feet diameter under a pressure of 2500 psi is approximately 25,000,000 pounds. Should bolts be used, each bolt would have a diameter of slightly more than six inches and approximately forty-five would be needed. It can be readily seen that if one utilizes bolts one does not have a "quick opening" vessel cover. There have

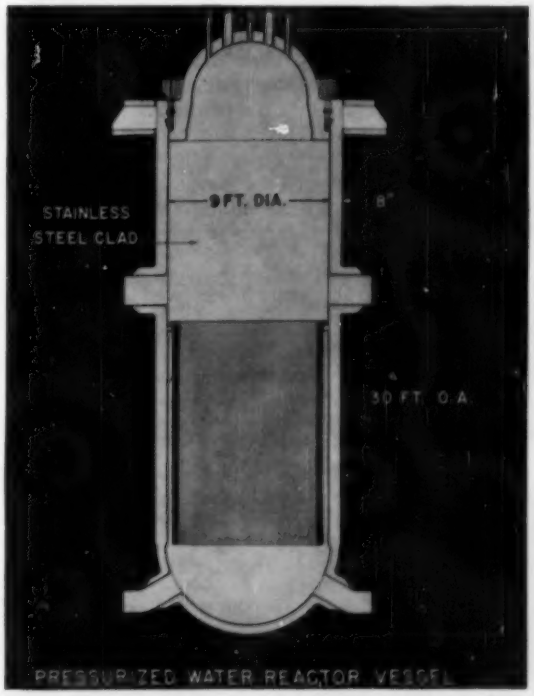


Fig. 3—Arrangement of reactor vessel

been other vessel cover hold down devices designed; one is illustrated in Fig. 3. This closure is an adaptation of the well-known shear-ring design. It consists of a number of conical segments which are dropped between the reactor cover and vessel wall and then rotated so as to form a compression ring between the vessel wall and cover. This design does require some development, but it is felt it offers some distinct advantages over the more common bolted closure. These advantages include a shorter required removal time, smaller closure components and improved load distribution.

Another problem in the vessel fabrication is that only a non-corrosive material must contact the coolant. Therefore all internal surfaces of the vessel must be clad with stainless steel.

The reactor vessel in a sodium system is not as critical, since the operating pressures are much lower. This vessel does, however, have its own unique problems. It is common practice to design this vessel with a double wall so that a safety barrier is provided for sodium leakage. It is also required to include electrical heaters in the assembly of the vessel so that the sodium can remain molten when the reactor is shut down.

Refueling

In the field of reactor design one phase of the process has received much less development than any other. This is the refueling of the nuclear core. Most nuclear system designs which have emanated from the National Laboratories have either overlooked or minimized the problems involved in stoking the nuclear furnace. Most of the research and test reactors are refueled manually. The equipment is cheap and time is not usually a factor. In a central power station, however, the length of time that a power-producing unit is shut down must be kept to a minimum. Manpower is expensive. The problems encountered in developing a fast, economical reloading system are numerous. It may be well to outline a typical reloading scheme for a Pressurized Water Reactor and then show possible methods of eliminating certain steps and reducing the required shut down time.

The reactor is usually buried in a concrete chamber. For reasons which will be covered in the next section the reactor vessel is enclosed in a larger pressure vessel. There usually is a concrete shield plug covering the larger vessel. The following steps are required to refuel the reactor after it is shut down:

1. The concrete plug must be removed and stored in an adjacent area.
2. The cover of the large vessel must be unfastened, removed and stored.
3. The hold down device of the reactor vessel cover must be removed and stored.
4. The reactor pit must be filled with water.
5. The reactor vessel cover must be removed.
6. The core hold down mechanism must be unlatched or removed, depending upon its design and construction.
7. Fuel elements are then removed individually from the reactor core and placed in an underwater storage pit.
8. If necessary, the control elements are removed and placed in an underwater storage pit
9. New control rods are lowered through the water shield into the core.
10. New fuel elements are lowered through the water shield into the core.
11. The core hold down device is replaced.
12. The reactor vessel cover is lowered into place.
13. The shielding water is drained from reactor pit.
14. The reactor vessel cover closure is replaced and fastened.
15. The outer vessel cover is replaced and fastened.
16. The concrete plugs are replaced.

To illustrate the time required to perform such an operation consider Step 3 above. Should the vessel cover be held down by bolts they must be heated with special elements in order to elongate them and relieve tension before they can be unfastened. Fortunately, there probably will be enough steel and water between the bolt head and the reactor core so that this device can be guided and operated by personnel in close proximity to the bolts. Let us further assume that it has been necessary to seal weld the reactor cover to the reactor vessel. A special cutting machine must be installed and must cut away the required weld metal. Considering the fact that this welded seam is forty feet in circumference, it can be readily seen that this operation will be a time-consuming one.

In light of the above it is evident that rigorous development must be given to a more practical and speedier unloading system. This is especially true in a reactor design where the integrity of the fuel elements is doubtful and a fuel element rupture is not inconceivable. A ruptured element must be removed as quickly as possible.

If a device could be developed that would speedily refuel the reactor without removing the reactor vessel cover, a large step would have been taken in the practicability of Pressurized Water Reactors.

A sodium system does not have the problems of high pressure and rugged, heavy vessel closures. The sodium coolant does, however, create problems. There may be difficulty encountered in removing fuel elements directly from sodium into the atmosphere. Sodium must also be completely sealed during reactor operations. Several schemes have been developed to refuel sodium reactors. One typical scheme would be to incorporate a pool of sodium above the actual reactor vessel and lift the element into this pool and then transport the element to a canal. This canal would in all probability be filled with a sodium gas. Access to the elements might be provided by eccentric plugs which can be rotated when the reactor is shut down, so as to give clearance ports through which unloading mechanisms can operate.

In the sodium system designs to date, as well as the Pressurized Water Systems, refueling procedures have been unwieldy and too time-consuming for practical central power station operation.

Pumps and Valves

The extreme low leakage requirement of reactor systems has been the greatest problem to the designer of the primary system circulating pumps and valves. Several pumps have been developed which will operate with zero leakage of the primary coolant. In most of these designs the rotating parts of the pump are totally immersed in the coolant. This type of pump is commonly called a canned rotor pump. The stator, or rotation inducer, is on the outside of the can and is externally cooled. To be con-

sistent with the water system leakage philosophy discussed earlier, it may be possible to use a circulating pump with some nominal amount of leakage, provided that leakage is consistent and controlled.

At the present time most reactor systems must be designed with canned pumps. These pumps are very expensive and as yet those sized over ten thousand gpm are developmental.

A leak-proof quick opening valve is more difficult to design. At this time almost any leak-proof valve of the size required in a central station plant is a developmental item.

The problems above are encountered to a greater degree in a sodium system. The development of the electromagnetic pump has been an effective solution to the pumping problem of a liquid metal system. An electromagnetic pump is expensive, extremely large and comparatively inefficient. Some reactor designs have considered using gas-sealed sump type circulating pumps. The seal development alone has been going on for years, but as yet a satisfactory solution has not been found. The valve problems are greater in a sodium system due to the deposition of sodium oxide on the moving parts, which cause valve operation to become uncertain.

Accident Containment

One other problem, at least for the time being, confronts the reactor system designer. Safety is a most important consideration of any proposed nuclear power plant. Each proposed plant must be reviewed by a Reactor Safeguards Committee. When a reactor plant operator submits his design for approval, he must also submit his definition of the "maximum credible accident" which might occur during plant operation. He then must provide means in the overall design for containing such an accident so that the safety of any surrounding area is insured.

A typical maximum accident of a Pressurized Water System would be that the reactor vessel or any portion of the primary loop ruptures during operation. The primary coolant would flash to steam and the steam would be radioactive. This steam must be contained. This is the reason for the larger pressure vessel mentioned during the refueling procedure. To contain such an accident the reactor primary loop and steam generator must all be contained in pressure tight vessels. Remembering that the reactor vessel has an outer diameter of approximately 11 feet and is approximately 35 feet high, one can imagine the size of a containment vessel. The pressure which must be contained will, of course, depend upon the volume of the vessel and the amount of water which has been calculated to flash into steam. Once the steam has been contained a controlled vapor release system must be included in the plant design.

Conclusion

This paper has illustrated some of the problems encountered by the nuclear power plant engineer and designer. Some of these problems are very difficult but none are insurmountable. Nuclear power plants have been built and have operated very successfully. They have proven to be stable, safe and efficient. To the engineer remains the problem of developing practical components that will render these plants economical for widespread central power application.

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Waste Heat Boiler Increases Thermal Efficiency of 8000 Barrel per Day Platformer

By K. OWEN

Shell Refining and Marketing Co., Ltd.

Refineries offer many opportunities for efficient utilization of waste heat. This is an interesting account of an unusual installation employing a forced-circulation boiler to generate steam at the Shell refinery in Stanlow, England.

WHEN Shell were planning an 8000 barrel per day Platformer for their refinery in Stanlow, England, a high thermal efficiency was one of the basic requirements of the plant, and to this end a forced-circulation boiler, manufactured by Combustion Engineering, Inc., of New York, was incorporated into the reactor heater of the plant.

Shell's Stanlow Refinery is a comprehensive refinery covering 1800 acres of ground. The refinery intake, mainly of crude oil from the Middle East, is five and a half million tons per annum and the crude oil section of the refinery comprises distillation, catalytic cracking, reforming, polymerization and treating units. There are also bitumen and lubricating oil plants, the latter being based on Caribbean crudes, and a chemical plant fed by light hydrocarbons from the crude refinery. Early in 1952 it was decided to build a UOP Platforming Unit for the purpose of manufacturing an aviation base stock for aviation gasoline from highly naphthenic Caribbean naphthas. The plant was designed jointly by Universal Oil Products, Ltd., and the Shell Group, and built by Universal Oil Products' English affiliates, Procon (Great Britain) Ltd. By maintaining the closest possible co-operation between all parties concerned in the project, construction was completed by the end of 1953. The plant went on stream satisfactorily and has been trouble-free in operation.

The Platforming Process

When manufacturing a component for aviation gasoline by Platforming a highly naphthenic naphtha, an important chemical reaction of the process is the dehydrogenation of cyclohexane and its derivates to form aromatics and hydrogen. Aromatics are also formed by isomerization and subsequent dehydrogenation of five membered naphthene rings. Further quality improvement is obtained by hydrocracking and isomerization of aliphatics. Aromatics also are produced by ring closure of essentially straight chain aliphatics.

The Stanlow Platformer

A flow diagram of the Platformer is given in Fig. 1. The naphtha feed is topped and tailed in a prefractionating unit. The heart cut thus prepared is mixed with

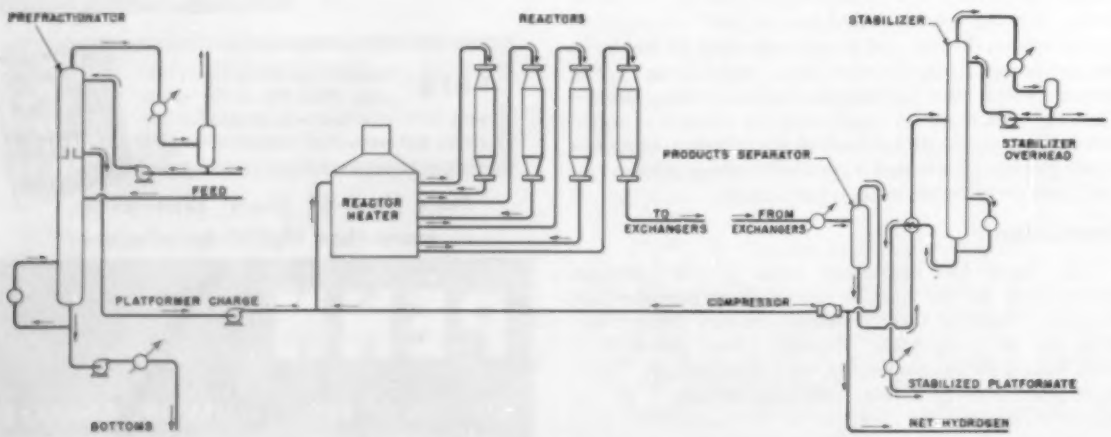


Fig. 1—Flow diagram of Platforming Unit

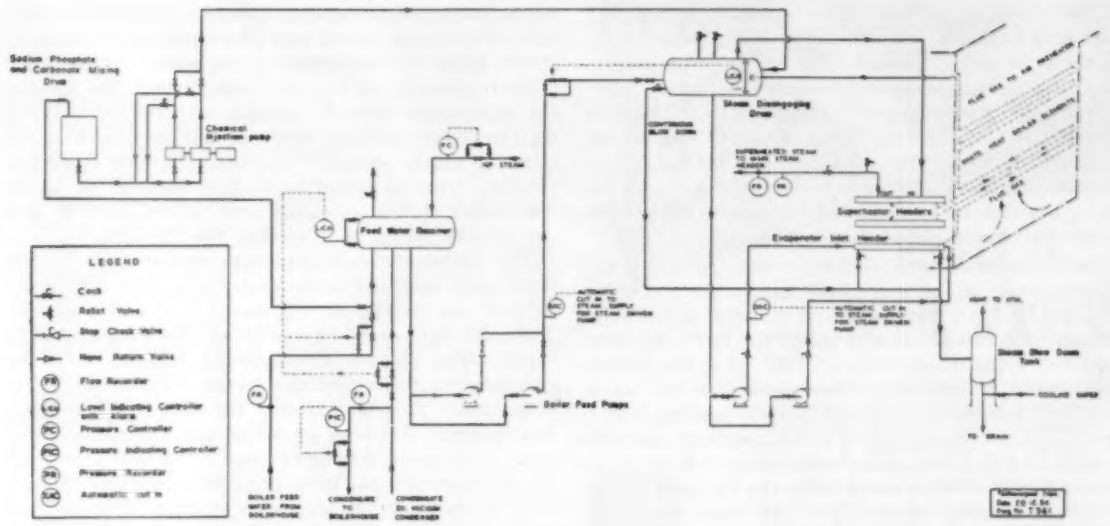


Fig. 2—Arrangement of waste heat boiler

recycle hydrogen of about 95 per cent volume purity, produced in the Platforming reaction, and fed through the reactor heater into the first of the four Platforming reactors. Because of the endothermic nature of the Platforming reaction there is a temperature drop in passing through the first reactor. Therefore, the effluent from the reactor has to be reheated in an interheating cell of the reactor heater before passing to the second reactor. Similar interheating is required after the second and third reactors.

The effluent from the fourth and last reactor passes through heat exchangers and coolers to the reactor products separator. A portion of the gas, which is about 95 volume per cent pure hydrogen, is recycled. The liquid from the reactor product separator flows first to a stabilizer for depentanization and then to a splitter column, not illustrated, where light and heavy platformates are prepared as top and bottom products, respectively.

Reason for Installing Waste Heat Boiler

It is the high temperatures of the reactor effluent feeds to the interheaters of the reactor heater that dictate the need for a waste heat boiler. These feed temperatures are 800 F or higher and therefore all interheating, that is to say all reheating of the process stream leaving one reactor and passing to the next, must be in the radiant sections of the heater. For compactness of design it was decided to combine into one main heater structure these interheater cells with the charge cells used for heating the charge entering the first reactor. Since this reactor charge is already heated by heat exchange with the reactor effluent before it enters the charge section of the heater, it was obvious that no more than a small part of the convection section of this large heater could be economically used for supplying heat to the reactor charge. Therefore it seemed that the neatest arrangement was to use none of the convection bank for process heating but instead to raise steam in the convection section. This scheme had the added advantage of economizing in alloy piping since all the heater tubes on the process side had to be of alloy steel for protection against hydrogen attack. By having all process heating by radiant heating rather than part radiant, part convection, the number of process heater tubes was reduced to the minimum.

The next point to decide was the type of waste heat boiler to be installed, the choice being between natural and forced circulation types. Here it was felt that forced circulation was the better choice since it would have been inconvenient to arrange for the necessary difference of hydraulic head to insure that at all times there would be an adequate rate of circulation through the boiler tubes. Forced circulation has the added advantage that it is a simple matter to arrange for the differential circulating pressure to be high enough to allow for the installation of restriction orifices, assuring that all tubes receive the same amount of water.

Description of Waste Heat Boiler

A flow scheme for the waste heat boiler is given in Fig. 2. Usually the boiler feed is deaerated and treated water from the refinery boiler feed water mains, but if desired condensate from the plant turbines can be used after treatment with sodium phosphate and sodium carbonate. Under normal conditions there is enough of this condensate available to run the boiler. There is a feedwater receiver, the level in which is automatically controlled by a valve in the feed line. This level is indicated on the panel in the Platformer control room. An alarm sounds on high or low level. A steam blanket of a few pounds pressure is automatically maintained on the drum to prevent ingress of air. When half full the feedwater receiver contains enough water to operate the boiler for half an hour.

One of two boiler feed pumps takes suction on the feedwater receiver and discharges into the steam disengaging drum. Both pumps were made by Pacific Pumps Inc. and are six-stage centrifugals designed to deliver 65 gpm at 400 psig, though normally the boiler operates at only 265 psig. One pump is driven by a 75-hp motor made by the Continental Electric Company and the other by a turbine made by the Terry Steam

Turbine Company. The turbine operates on 220-psig steam and exhausts to the refinery low pressure main running at 45 psig. Normally the electric pump is operating, the turbine being instrumented to cut in automatically by pressure switch on failure of the electric drive. It is vital that the boiler should be able to run safely during an electrical failure since, for reasons of catalyst protection, hydrogen recycle and firing of the reactor heater must be continued for some time after the electric-driven unit-charge pumps have cut out.

The boiler feed pump discharges into the steam disengaging drum of the waste heat boiler. This vessel is 4 ft diam by 11 ft, 6 in. long, and the level in it is automatically controlled by a valve in the feedwater line. The level in the steam drum is indicated in the control room, and on high or low level an alarm sounds. As an additional safeguard, mounted directly on the boiler, there is a Yarway hi-low level alarm operating a whistle on high or low level. The total solids content of the boiler water is maintained at 2000 ppm by hand control of the continuous blowdown from the steam drum.

There are two pumps for circulating the boiler water, one electric and one turbine driven. The pumps are by Ingersoll-Rand and each is capable of delivering 496 gpm to a differential head of 114 ft. The electric drive is by General Electric and the turbine drive by the Terry Steam Turbine Company. Under design conditions the rate of circulation is 11 times the rate of feedwater injection. The turbine is instrumented to cut in on low circulating flow of boiler water and for additional safety an alarm also sounds on low flow.

The evaporator and superheater elements form a bundle 8 ft, 2 in. wide by 6 ft, 7 in. high by 28 ft, 5 in. long and comprise the whole of the convection section of the reactor heater. Flue gas from the three charge and three intermediate heater cells of this heater, which is on forced draft, flow upward through these elements. Uniform distribution of flue gases across the superheater is assured by providing straightening vanes in the outlet duct. For economy and ease of construction the refractory of this furnace consists of 5-in. thick precast panels of Haydite in place of normal brickwork.

The circulating pump discharges to a header into which are tied the 58 evaporator elements. In order to assure uniform distribution of flow between these 58 elements, each one is provided with a restriction nozzle protected from clogging with scale by a stainless steel screen. Each element consists of 200 ft of mild steel tubing $1^1/_2$ in. OD by 0.135 in. minimum wall thickness. This piping is led back and forth across the convection space eight times, the return bends being integral with the rest of the piping. The tubes are on $3^1/_2$-in. centers in the rows and the rows are on $2^3/_8$-in. centers. The elements discharge into an outlet header which is led back into the steam disengaging drum. The water in this effluent flows back to the circulating pump, while the saturated steam flows through a dry box in the steam drum to the header leading to the superheater elements. The superheater elements consist of 49 × 30 ft lengths of mild steel tubing $1^1/_2$-in. OD by 0.135-in. minimum wall thickness bent into the form of hairpins. Center to center spacing in the rows is $3^1/_2$-in. and between the rows, $2^3/_8$-in. To insure a good rate of heat transfer the nest of superheater elements is installed in the lower part of the bundle which receives the entering flue gases, but to prevent tube damage through receiving too much radiant heat one double row of evaporator elements is fitted below the superheater elements. A knockout drum is provided on the superheated steam line leaving the superheater elements because, with the steam being used to power 4000-rpm turbines, it is essential that the latter be amply protected against condensate carryover resulting from an exceptionally high level in the boiler. The outlet of this knockout drum is tied directly into the refinery steam main feeding the Platformer.

Two electric-driven soot blowers are provided. One is installed at each end of the heater in a space 3-ft, 10-in. high in the middle of the waste heat boiler bundle. There are eight rows of tubes above this space and eight below. The blowers automatically traverse with one complete rotation every two inches. Reversing is also automatic. To guard against the danger of the lance tube warping if it were propelled into the furnace with little or no steam flowing through it, there is a pressure switch to prevent the lance being traversed into the furnace in the event of there being insufficient pressure of steam on the jet of the soot blower.

An interesting feature of the plant is the graphic panel in the control room. The following instruments for the waste heat boiler are included in the panel.

Feedwater receiver	level indicator
Feedwater receiver	high and low level audible and visible alarms
Steam disengaging drum	level indicator
Steam disengaging drum	high and low level audible and visible alarms
Steam production	flow and pressure

Design Data and Operating Experience

The plant has been operating for twelve months. During this period the mechanical performance of the

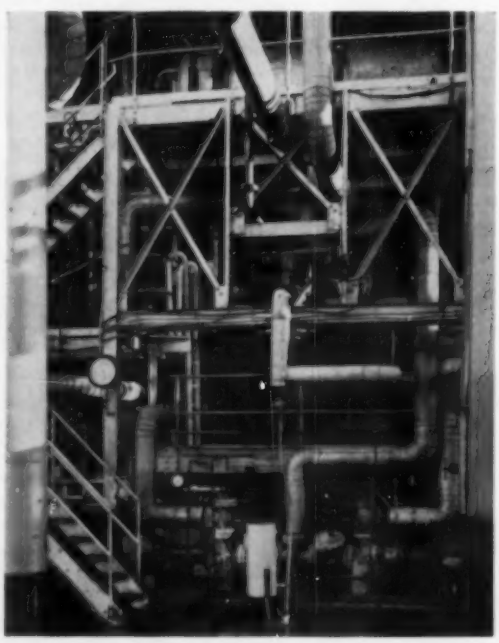


Fig. 3—Side view of waste heat boiler

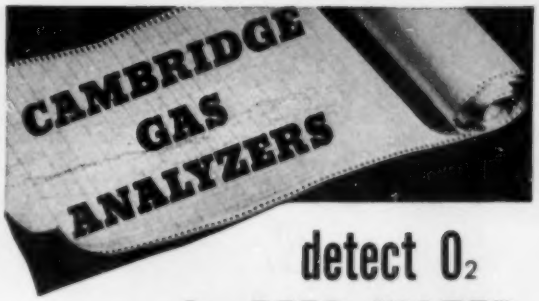
waste heat boiler, and indeed of all the equipment in the plant, has been excellent.

The design data for the superheater are given below:

Pressures, psig	
Design pressure	350
Operating pressure (superheater outlet)	256
Hydrostatic test (maximum)	575
Safety valve settings	
Steam drum	345–350
Superheater	280
Temperatures, F	
Waste gas entering boiler	1425
Steam at normal rating (superheater outlet)	650
Feedwater to steam drum	120
Ambient air	60
Evaporation, lb per hr	
Normal rating, steam	20,200
Waste gas	170,400
Heating surface, sq ft	
Evaporator	4,670
Superheater	570
Weights, lb	
Total cold water to fill unit completely	16,800
Cold water to fill boiler to normal level	10,720
Cold water to fill superheater	1,200
Water, steaming condition	9,150

In actual operation the quantity and temperature of the entering flue gases are somewhat below design. Nevertheless the waste heat boiler normally generates some 16,000 lb per hr of steam at 265 psig, superheated to 600 F. However, considerably more steam may be raised by running the reactor furnace at increased excess air rates. This facility is very useful in times of steam emergency which may arise in the refinery when other large producers of steam, such as the catalytic cracker are in trouble. Then by opening the stack dampers it is possible to generate sufficient steam for the Platformer to become independent of external supply.

The flue gases leave the waste heat boiler at a temperature of 770 F and then pass to a Ljungstrom regenerative type of air preheater. The overall thermal efficiency of the reactor heater, including waste heat boiler and air preheater, is 83 per cent which compares favorably with the design figure of 80 per cent.



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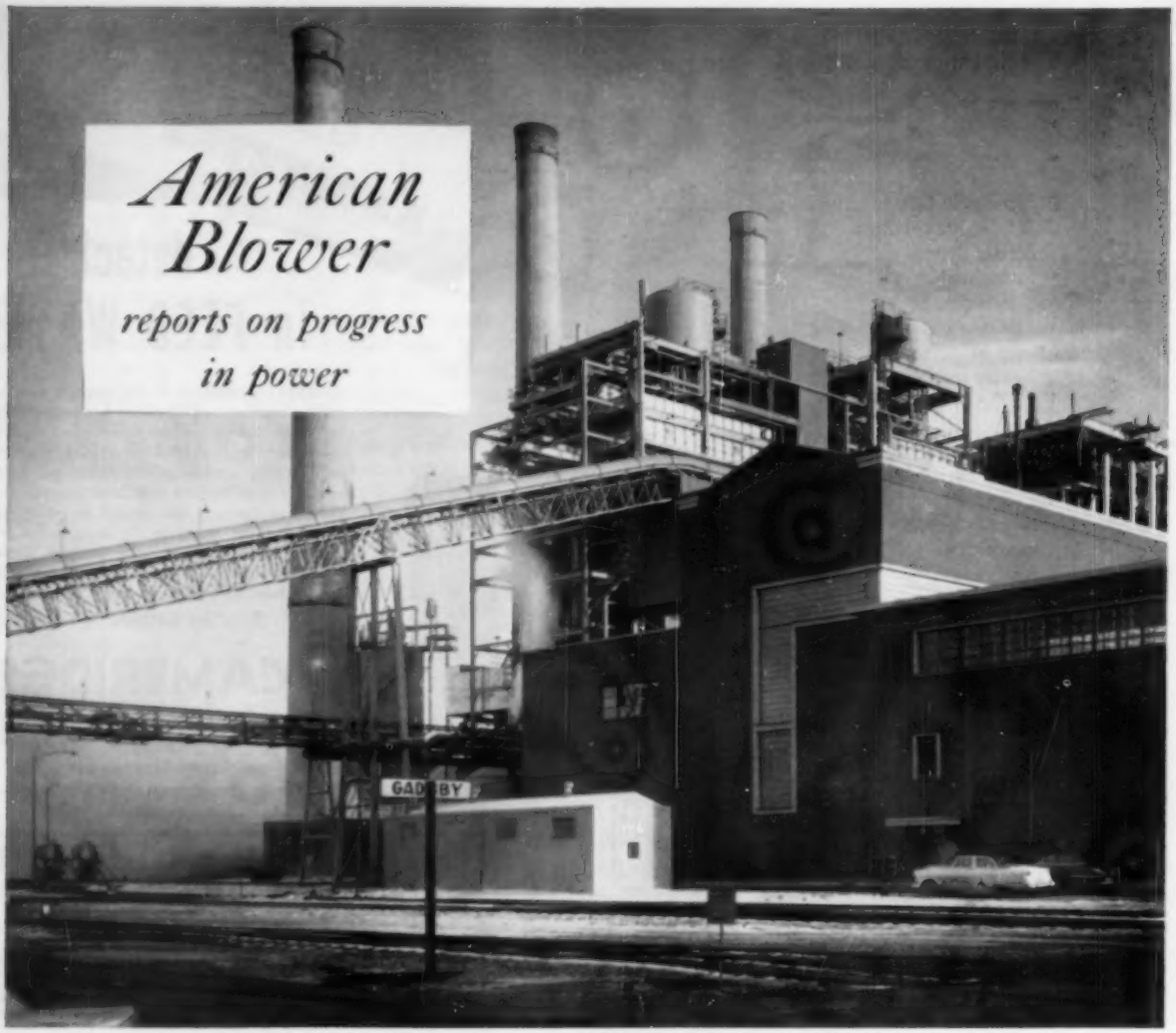

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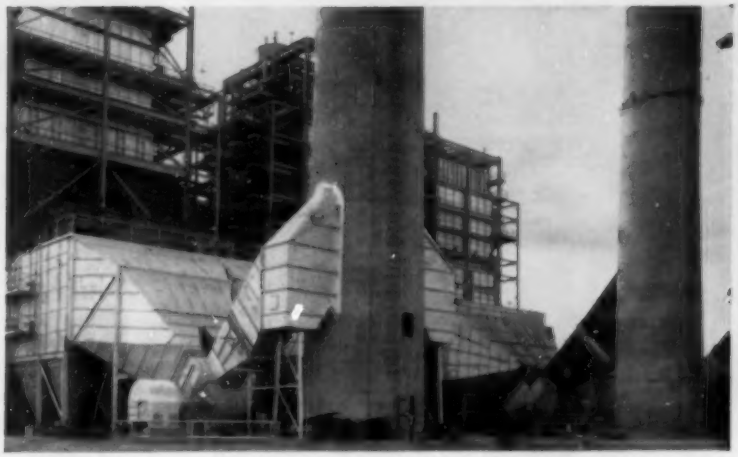
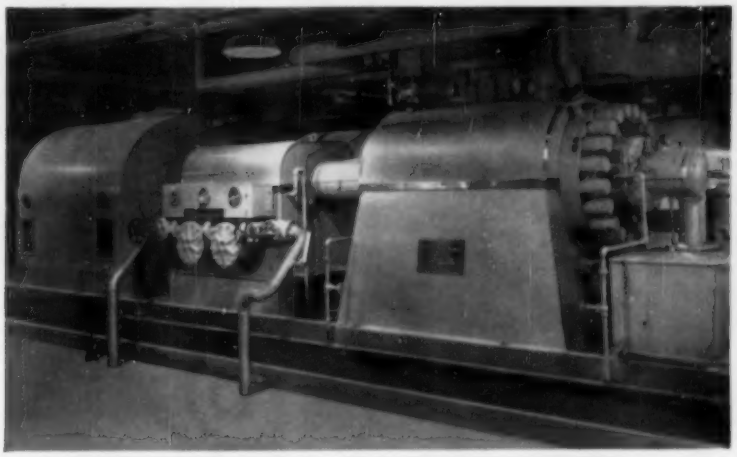


Completed in June 1955, UP & L's new 100,000 kw No. 3 unit (left) boosts Gadsby Plant capability to 241,000 kw. The unit's two American Blower Sirocco Induced Draft Fans are each rated @ 260,000 cfm @ 325° F @ 15.5" sp @ 860 bhp. American Blower equipment is also installed on units No. 1 and No. 2.



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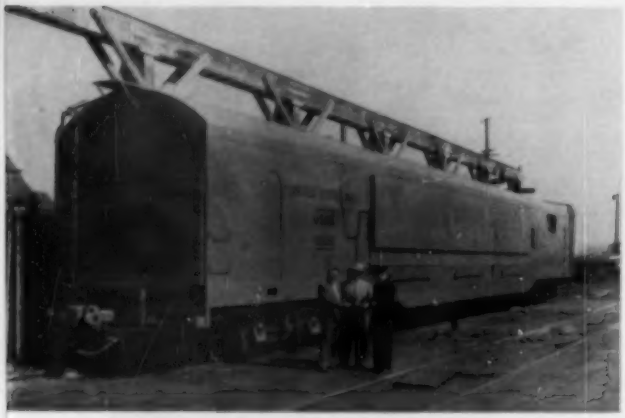
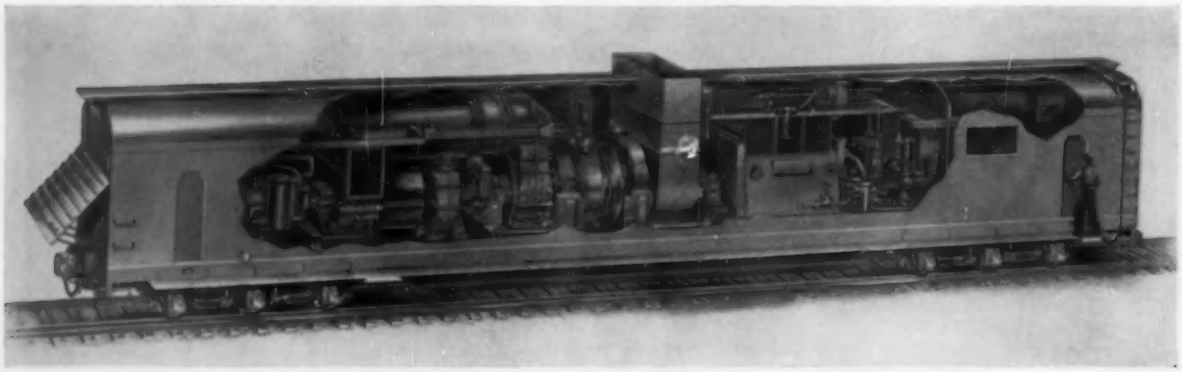


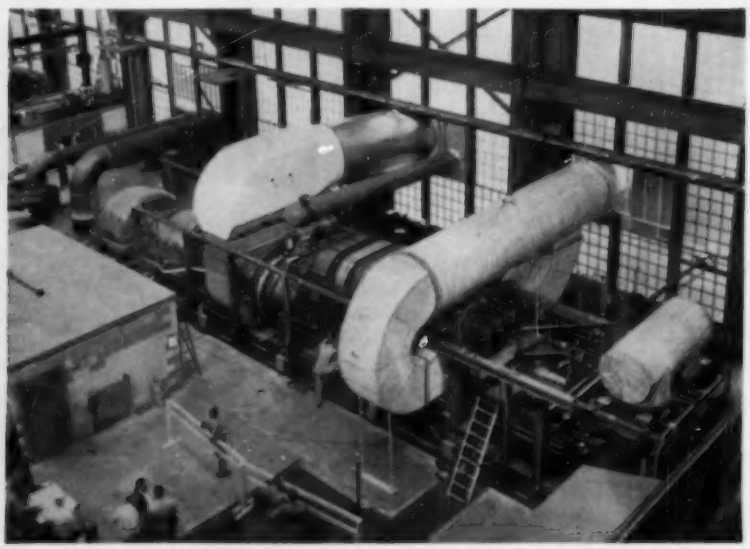
The railroad car is of special design to assure maximum support for the gas turbine, generator and auxiliary equipment

Early in July, Clark Bros. Co. of Olean, N.Y., one of the Dresser Industries, demonstrated a mobile dual-shaft simple-cycle gas turbine capable of developing 5500 kw. The unit is mounted on a single railroad car and, upon arrival at its destination, can be operated by connection to fuel and transmission lines. It was built for the Bureau of Yards and Docks of the U. S. Navy to serve as a compact, mobile source of electric power useful in an emergency.

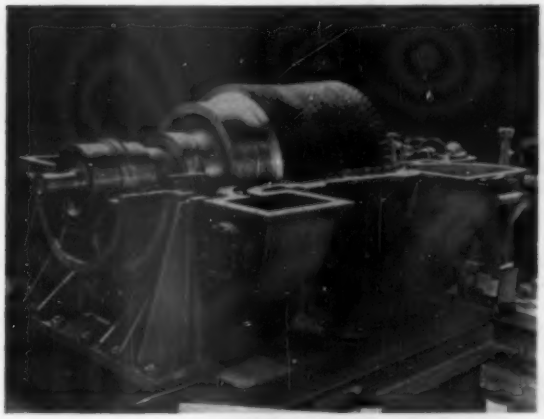


In this cutaway the diesel engine for starting is at left, followed by the gas turbine, generator, exciter, fuel pumps and control room. Turbine exhaust is at center

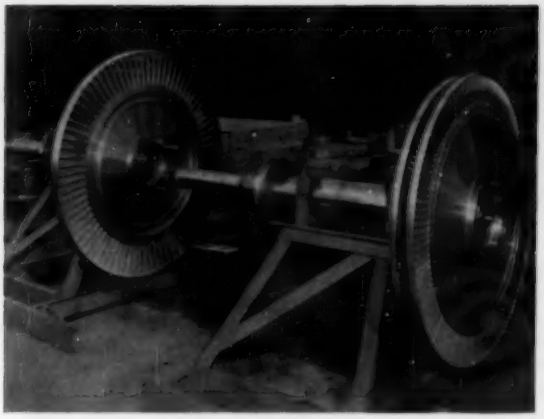
Fully enclosed dead-front switch gear is used in the compact control room



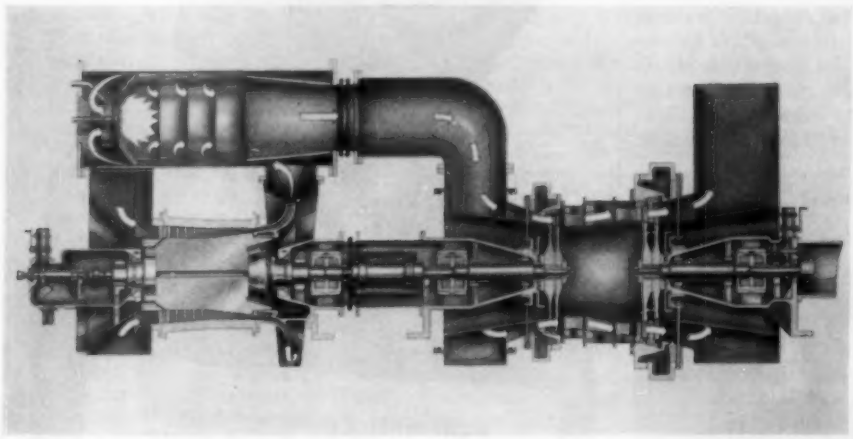
This is a view of the gas turbine undergoing test at Olean, N. Y. No part of the outer surface has a temperature exceeding 200 F



The axial compressor is of the horizontally split case design. It is a 13-stage unit designed for a pressure ratio of 4.25 and for delivery of 100 lb per second

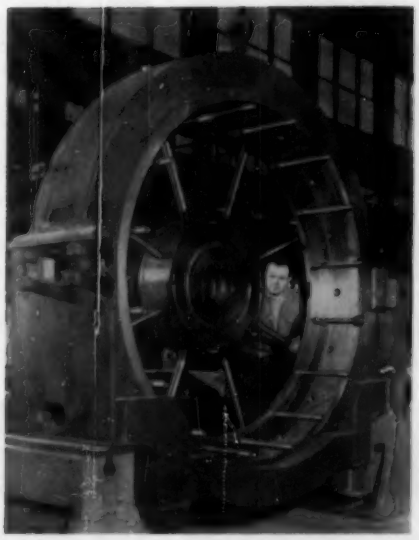


The high- and low-pressure turbine wheels shown in this view have short shafts to simplify alignment. A flexible duct conducts gases from one to the other



Air enters the axial compressor at lower left and is discharged into combustion chamber at upper left. The hot gases then enter the high-pressure turbine, center, which drives the compressor. Next they pass through the low-pressure turbine, right, which drives the generator. The gases are exhausted to the atmosphere through the car roof

Three burners are installed in counter-flow design combustion chamber



Both turbine cases are supported in air-cooled "cold rings" of type shown

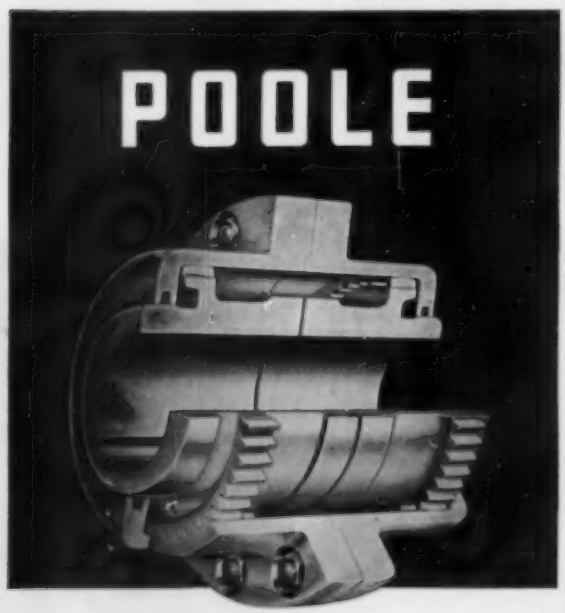
Turbine blades are anchored with fir-tree serrations

Pulverized Coal in Great Britain*

The advance of pulverized coal firing, "Combustion of Pulverized Fuel for Steam Generation" by **W. F. Simonson,** Water-tube Boilermakers' Assn., is associated with the postwar policy of the British Electricity Authority, which came into being in 1948, of adopting the unit combination of boiler and turbine in capacities of 30, 60, and 100 mw for straight condensing sets, and of developing the reheat cycle for units of 120 and 200 mw. Such unit capacities are beyond the scope of the stoker-fired boiler and this policy has only been made possible by the success which has attended the development of pulverized-fuel-firing techniques.

For the boiler designer, pending the results of long-term research work, an overriding BEA request for boiler units capable of two-shift operation enjoins overall liberality of design, affording ample furnace capacity to maintain heat-release rates per unit volume at moderate levels and providing adequate radiant-heat absorbing surfaces to ensure safe gas-exit temperatures in relation to the ash-softening and fusion characteristics. Equally, it necessitates the incorporation of such practical features as the adoption of wide spacing of tube surfaces to prevent the accumulation of deposits, and adequate arrangements for on-load cleaning, including careful disposition of soot-blowers and the provision of suitable pockets, at appropriate points of gas-flow reversal for dust removal.

* From a paper presented at the International Combustion Conference sponsored jointly by ASME and IME and held on the campus of Massachusetts Institute of Technology, July 14–17, 1955.



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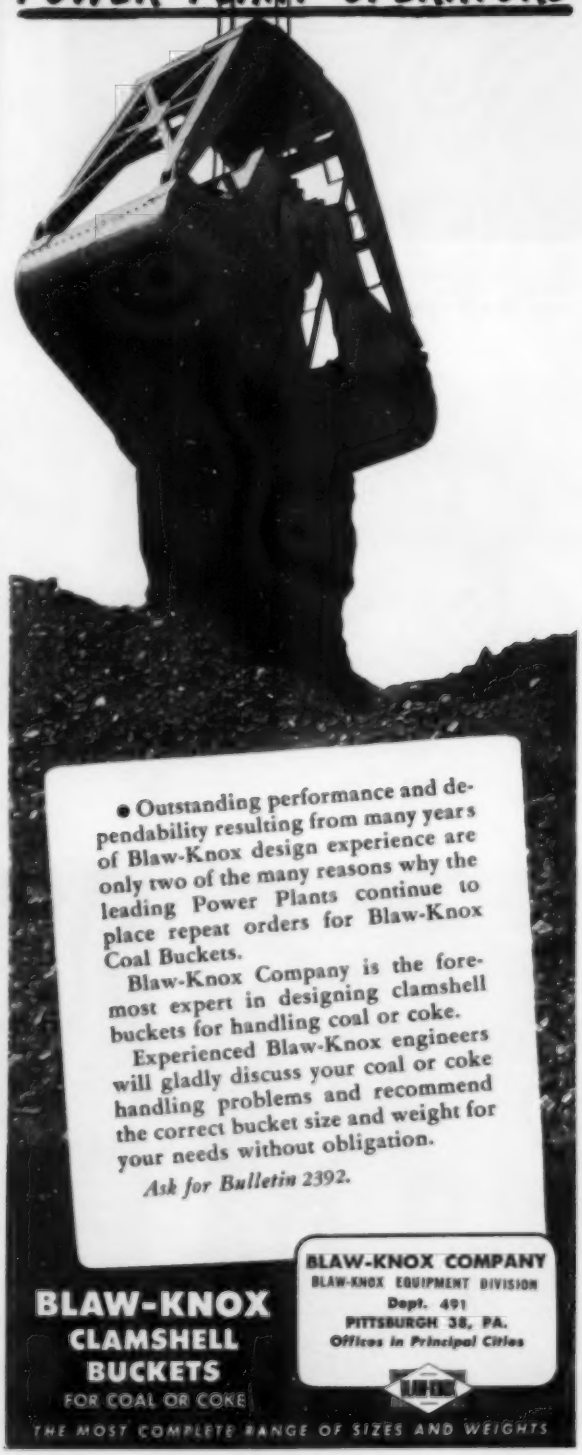

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Report of the Committee on Evaluation of Engineering Education*

Since its founding in 1893 the American Society for Engineering Education has made many studies of engineering curricula. Because of the influential nature of these authoritative evaluations and their effect upon engineering education in the years following presentation of the reports, we feel that our readers will find of interest the following extracts from the most recent report dated June 15, 1955. Throughout the report emphasis is placed on strengthening scientific areas of instruction and integrating work in the humanistic and social sciences into the engineering curriculum.

Engineering is far from static, for it is essentially a creative profession. It has played a dominant role in building American industrial superiority, in developing the principle of mass production, and in giving the American people their high standard of living. The continuing growth of our knowledge of basic science has opened vast new areas to engineering endeavor and has enlarged the foundations underlying many of the existing engineering fields. Some fields of engineering have been reasonably alert in assimilating new scientific advances into their teaching programs. It is one purpose of this Report to encourage *all* fields of engineering education to move in this direction.

Any attempt to specify the content of an engineering curriculum must be preceded by the development of a clear understanding of the objectives of such professional education. These objectives are twofold and are based in the technical and social responsibilities that must be assumed by graduates expecting to enter the engineering profession. The entire professional educational process is more inclusive in scope than an undergraduate engineering curriculum, for it also includes training in high school and postbaccalaureate study in a university or in industry, along with continual self-study and with experience in engineering practice before full professional status can be achieved.

Technical and Social Goals

The first objective, the technical goal of engineering education, is preparation for the performance of the functions of analysis and creative design, or of the functions of construction, production, or operation where a full knowledge of the analysis and design of the structure, machine, or process is essential. It also involves mastery of the fundamental scientific principles associated with any branch of engineering, including a knowledge of their limitations and of their applications to particular problems, such as the development of materials, machines, or structures as well as the ability to make critical scientific and economic analyses and to organize these into clear, concise, and convincing oral or written reports.

The second objective, the broad social goal of engineering education, includes the development of leadership, the inculcation of a deep sense of professional ethics, and the general education of the individual. These broad objectives include an understanding of the evolution of society and of the impact of technology on it; an acquaintance with and appreciation of the heritage of other cultural fields; and the development of both a personal philosophy which will insure satisfaction in the pursuit of a productive life and a sense of moral and ethical values consistent with the career of a professional engineer.

These technical and social objectives should be met in a manner which will provide the individual with an enlightened background that will give him the means and the inspiration to grow on his own initiative before and after graduation. An undergraduate curriculum must serve a twofold purpose of preparing some men for immediate employment and others for graduate study. This Committee believes that in any one field a curriculum with a reasonable degree of flexibility, as represented by electives, can meet both of these needs.

The Selection and Development of an Engineering Faculty

Distinguished faculties are far more important to the advancement of engineering education than details of curricula or magnificence of facilities. The university is a community of scholars and as such requires outstanding teachers to attract outstanding students. To improve and develop courses or curricula, to build up facilities—in short, to command respect as an educational institution—all require a faculty of competent teachers and scholars.

The academic and professional development of an engineering faculty can proceed only in a favorable environment. More important than physical surroundings is the intellectual atmosphere; that is, the attitudes and ideas of the people who comprise the university. A common inner urge to know and to understand is basic to this atmosphere and leads to unity of purpose—the mutual selection of common goals and coordination of effort toward their achievement. There must be encouragement of intellectual growth and opportunity for professional development such as is involved in the teaching of graduate courses. Teaching loads must be kept at reasonable levels to allow time for scholarly or creative activities. The development of such a favorable academic atmosphere should be the concern of all faculty members, particularly those in senior administrative posts.

The atmosphere of a university has a significant influence on student progress. Students need a close bond of mutual interest and friendship with members of the faculty. They need objective guidance and encouragement in their intellectual growth; they need sympathetic understanding of their personal problems; but above all, they need the realization that they are being treated as individuals. An administration and a faculty which are genuinely concerned with these responsibilities are most likely to create a favorable student environment.

Qualifications of Teachers

Any teacher at the university level must have notable intellectual capacity and a sustained interest in a life of

* Excerpts from a report presented at the 63rd Annual Meeting of the American Society for Engineering Education at Pennsylvania State University, June 20-24, 1955. Chairman of the 46-member committee was Dr. L. E. Grinter, Dean of Graduate School at the University of Florida.

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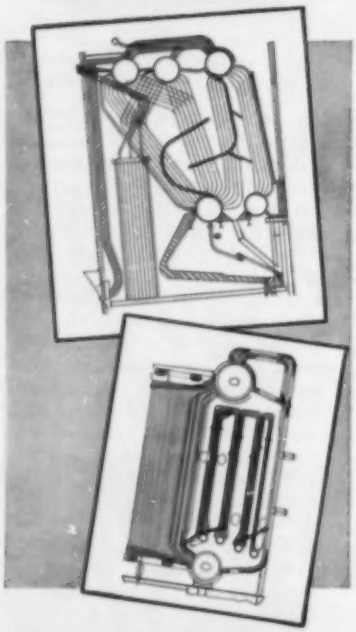

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study for continuing mastery of his field—obvious qualifications that nevertheless merit explicit statement. To teach well, he must know and understand, clearly and in perspective, his own and supporting fields at a much more penetrating level than that required in his lectures.

The engineering teacher, in addition, must have a full appreciation of the goals to be achieved. He should realize, first of all, that a course can be taught either as a narrow specialty or as a liberal subject in a professional curriculum; he should strive for the latter. Such a liberal course is one in which the teacher inspires his students toward creative endeavor and intellectual development not only while they are in college but also throughout their careers. It is one into which he brings recognition of the importance of intellectual honesty and professional integrity. To achieve these goals he should possess energy, enthusiasm, and a sincere interest in the development of men. To be fully successful he must exercise judgment and tact, and have the ability to meet the minds of his students. *He should perform creative work whether it be in teaching, writing, research, or professional activities.*

Education and Experience

For a relatively young candidate for a faculty position, the strongest evidence usually available to measure a background of integrated fundamental knowledge and probable creative ability in teaching and research is an education which includes the doctor's degree. However, unless an academic environment is provided that will stimulate and retain men with an interest in creative work, mere insistence on degrees will not insure high quality in a faculty. For experienced persons, evidence of the capacity of the individual for creative teaching and research may be gaged by other criteria, and the formal educational background is of less significance.

Development of a Faculty

It is important that faculty members set an example for their students by their membership and active participation in professional and technical societies, by becoming licensed engineers, by study of current literature, and by demonstrating interest in new developments and in research. Such leadership among faculty members is particularly necessary in institutions that are able to provide only limited opportunities for research, for leadership contributes an important element of vitality to teaching. The spirit of leadership that also creates in the student a desire to lead is of the greatest importance. It can be developed by teachers who are men of stature, judgment, wisdom, and tact. The ambition for leadership should involve ascendance in a technical field and a desire to serve society.

In engineering teaching, continual contact with the forefront of engineering and scientific progress is essential. Leadership in scientific and engineering progress has frequently stemmed from university research activities. *The engineering teacher carries a responsibility to contribute to the advancement of knowledge through engineering research. The university must provide the opportunity to realize this objective in terms of time, facilities, and assistance.*

Consulting practice should be considered as a means of developing and further strengthening an engineering faculty. Close association with engineering work or research in industry should stimulate the teacher and improve his teaching. Consulting is also a source of ideas for research. The limit upon the useful extent of this activity has not been determined. However, the belief is widely accepted that an average of one day per week of the individual teacher's time devoted to consulting activity of a high professional character will reflect to the overall advantage of the institution.

Curricular Content as Related to the Objectives of Engineering Education

The instructional goals of engineering education include helping the student to learn to deal with new situations in terms of fundamental principles, on his own initiative, with confidence and sound judgment. The goals should include motivation to keep abreast of the new developments in science and technology and to continue to grow intellectually in both professional and cultural areas throughout life.

In professional engineering practice the "new situation" often involves social and economic as well as technical elements, and these are not entirely separable. Thus the end result is not merely the numerical solution of a technical problem but is rather a decision based on a value judgment to which the quantitative technical result contributes one important element. In fact, the significant problems involving engineering seldom occur in well-defined form. Hence, the initial stage of thinking is often an intuitive groping to identify specific component problems. Their solution, in turn, requires the application of thoroughly understood fundamental principles and well-ordered analytical thinking in defining the problem, planning its simplification without losing its essential nature, conceiving a method of attack, carrying the study through to a successful conclusion, and checking the results at each stage. This technical

solution is then available to guide the engineer when he considers the broader social and economic aspects of the problem. His final decision will be influenced by the extent to which his perspective and judgment transcend purely technical matters.

Engineering educators must never lose sight of the broad issues with which large engineering problems are always associated, although the ability to deal effectively with such broad issues comes only with experience and maturity in the years after college. The importance of keeping such economic and social ideas before students by example can hardly be overemphasized. Such concepts should be encompassed even though the main effort at the undegraduate level is largely restricted to developing the student's ability to master the scientific and technical aspects of engineering education.

Assimilating New Scientific Material

It seems evident that the frontiers of science and technology are now advancing at a more rapid rate than at any previous time, and that many of today's frontiers will be reduced to significant engineering practice in the years ahead. Furthermore, these newly developed frontiers illuminate the older fields with new concepts and give them increased vitality. It is a responsibility of the engineer to recognize those new developments in science and technology that have significant potentialities in engineering. Moreover, the rate at which new scientific knowledge will be translated into engineering practice depends, in a large measure, upon the engineer's capacity to understand the new science as it develops.

This translation of new scientific development into engineering practice will be facilitated by emphasizing unity in scientific subject matter. For example, there is a great deal of similarity, both in conceptual understanding and in analytical methods, among the generalizations of heat flow, mechanics of fluids, electromagnetic fields, and vibration theory. When a student understands these generalizations, he has gained a concept of systematic orderliness in many fields of science and engineering; he is therefore able to approach the solution of problems in widely diverse fields, using the same analytical methods. This unification of methods of analysis can be accomplished to a considerable degree without reaching beyond undergraduate mathematical levels. It can be accomplished to a much greater degree by utilizing advanced mathematical concepts.

Looking at the subject of instructional goals even more broadly, one concludes that the engineer should be a

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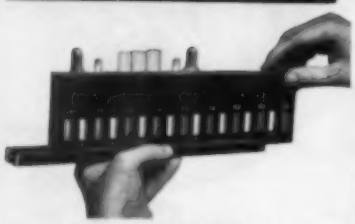

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well-educated man. He must be not only a competent professional engineer, but also an informed and participating citizen, and a person whose living expresses high cultural values and moral standards. Thus, the competent engineer needs understanding and appreciation in the humanities and in the social sciences as much as in his own field of engineering. He needs to be able to deal with the economic, human, and social factors of his professional problems. His facility with, and understanding of, ideas in the fields of humanities and social sciences not only provide an essential contribution to his professional engineering work, but also contribute to his success as a citizen and to the enrichment and meaning of his life as an individual.

Hence, instructional goals include motivating students and providing them with stimulating opportunities to gain understanding and appreciation of our historical and cultural heritage. This requires that the faculties of the humanities and the social sciences regard the teaching of engineering students as challenging and rewarding, and that engineering faculty members adopt an appreciative and understanding attitude toward their colleagues in the liberal arts.

Education for the profession of engineering does not stop with the acquisition of a degree; it must continue throughout life. Hence, one of the significant instructional goals of engineering education is to motivate the student to learn on his own initiative.

Evolution of Engineering Curricula

The great changes in physics and chemistry over the past thirty years and the equally great advances in engineering practice do not seem to have produced an equivalent counterpart in a reorganization of engineering curricula.

It is relatively easy to look backward and recognize changes; it is more difficult to visualize what lies ahead. After facing many questions regarding the future of engineering practice, one is likely to conclude that the teaching of practice, as it exists today, will always be of limited use because the graduate is certain to find practice changing from year to year. And, as a matter of fact, the engineering art taught in colleges will normally reflect practice that is already obsolete in part, since the teacher's knowledge of practice becomes rapidly outdated.

But fortunately, some things do not change. Reactions, stresses, and deflections will still occur, and they will have to be calculated. Electrical currents and fields will follow unchanging laws. Energy transformation, thermodynamics, and heat flow will be as important to the next generation of engineers as to the present one. Solids, fluids, and gases will continue to be handled, and their dynamics and chemical behavior will have to be understood. The special properties of materials as dependent upon their internal structure will be even more important to engineers a generation hence than they are today. These studies encompass the solid, unshifting foundation of engineering science upon which the engineering curriculum can be built with assurance and conviction.

Opportunity for Scientifically Oriented Curricula

The consideration of curricula cannot proceed wholly on a philosophical or qualitative basis but must eventually be approached quantitatively in semester hours or at least in terms of fractional percentages of the total program. The Committee on Evaluation, in order to clarify for itself the practicability of its suggestion that curricula of the usual type can be designed with an enhanced scientific orientation, has developed for consideration the broad outline of scientifically oriented curricula. *It intends this skeleton curriculum to be considered as suggestive rather than restrictive. The great need of engineering education at this time is for experimentation with, rather than standardization of, curricula.*

In defining an engineering curriculum the Committee on Evaluation has first indicated the need for *mathematics through differential equations;* however, another application of calculus, such as mathematical statistics and probability, might fit more effectively into industrial or sanitary engineering. Nevertheless, for many existing curricula this means at least one additional course in mathematics. The recommendation that *physics should be extended through an introduction to modern physics* will require more than the usual eight semester hours of sophomore physics, even though some time may be saved by elimination of problems involving semi-engineering applications. There is a growing belief that *some acquaintance with organic chemistry and a working knowledge of physical chemistry is essential to all engineers* and that this objective cannot be accomplished within the usual course in freshman chemistry. For most curricula these changes in mathematics, physics, and chemistry would probably require a total of at least six semester hours of additional study.

The second major factor in the original definition of scientifically oriented curricula included nine engineering sciences in sufficient strength to justify their separate listing. *These have now been regrouped into six engineering sciences:* (1) Mechanics of

solids (statics, dynamics, and strength of materials), (2) fluid mechanics, (3) thermodynamics, (4) transfer and rate mechanisms (heat, mass, and momentum transfer), (5) electrical theory (fields, circuits, and electronics), (6) nature and properties of materials (relating particle and aggregate structure to properties). *These titles should be regarded as generic and broadly definitive rather than as representative of courses now being offered.* In regrouping the engineering sciences into six categories, the Committee made no reduction in the minimum time considered appropriate for their study, which represents one quarter of the engineering curriculum.

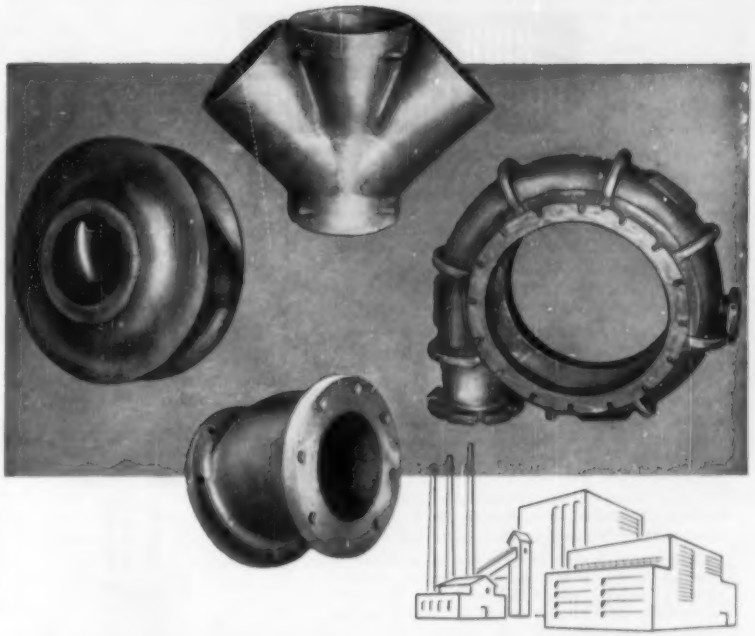
The third major element in the definition of an engineering curriculum is that it must contain an integrated sequential study. By this is meant that mathematics and the basic science shall be used proficiently in the courses in engineering science and that the latter, in turn, shall be used proficiently in engineering systems, and in the preparation for creative design work. For the scientifically oriented approach it seems desirable that analysis, synthesis, and creative design cover four successive semesters at an intensity to be represented by five or six semester hours per semester.

In addition to basic science, engineering science, and engineering analysis and design, allowance may be made for a minimum three-credit-hour humanistic or social science course each semester for at least seven or eight semesters and also for a small amount of required technology. The general outline of any scientifically oriented curriculum may therefore be described in five blocks of courses under the following headings: humanistic and social studies, mathematics and basic sciences, engineering sciences, engineering analysis and design, and electives.

Personals

Ralph L. Brown of Albany, N. Y., has been made a director of industrial sales of Vitro Engineering Division, New York City, a division of Vitro Corporation of America. Mr. Brown comes from Merco Centrifugal Company of San Francisco, Calif., where he has been Eastern sales representative since 1953.

According to a recent announce-



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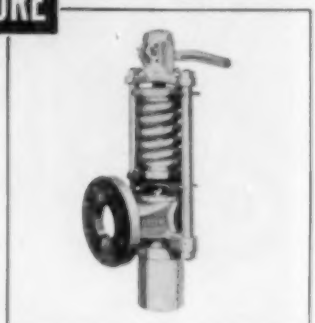

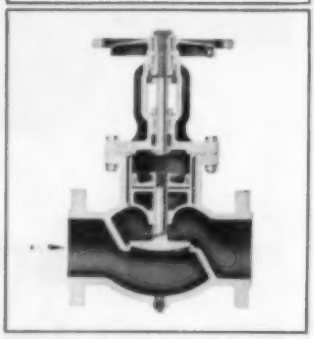

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ment by the firm's board of directors, **Robert S. Stevenson,** executive vice president of Allis-Chalmers Manufacturing Co. since July 1952, has been elected president. He succeeds the late William A. Roberts.

T. P. Jones has been named assistant manager of the Atlantic region of the Westinghouse Electric Corporation, with headquarters in Philadelphia. In addition, **T. E. Stieber** has been named Philadelphia district manager for the company and **Robert N. Anderson** has been appointed electric utility manager, Atlantic region.

Three Detroit Edison men have won their company's annual Alex Dow Award for outstanding achievement. They are **Henry P. Johnson,** bridgeman foreman, **George W. Matthews,** assistant district customer business superintendent, and **Rudolph Miesel,** senior planning engineer. Each of the winners received a citation, a gold lapel pin, and engraved watch, and five shares of Detroit Edison stock.

Don F. Steinke, a director of power education for The Dow Chemical Co. for several years, has accepted a position with the Standard Vacuum Petroleum Maatschappij, of The Hague, Holland, as overseas coordinator of training. The firm is a wholly-owned subsidiary of Standard Vacuum Oil Co.

The C. O. Bartlett & Snow Co. has announced the appointment of **Norman R. Kidd** as manager of its service and parts sales division. In this new position, Mr. Kidd will head up the department that services the company's specially engineered installations, and be responsible for the sales of various parts.

H. R. Fosnot, sales manager, Graver Water Conditioning Co., New York City, has announced the appointment of **J. D. Crell** as sales engineer for the New York City sales district. Mr. Crell has been with Graver for several years and is completely familiar with all phases of industrial, municipal and industrial waste treatment.

The retirement of **Vincent P. Rumely,** senior vice president and member of the board of directors of Crane Co., has been announced. Mr. Rumely became associated with Crane Co. in 1937 as a production engineer.

The elections of **Robert P. Tibolt** as executive vice president and **Allen C. Johnson** as an assistant vice president were announced by E. H. Bird, president of Eastern Gas and Fuel Associates.

Edward F. Harrington has joined the staff of the sales development department of Tube Turns, Louisville, Ky. The announcement was made by John G. Seiler, executive vice president and general manager of Tube Turns, a division of the National Cylinder Gas Co., Chicago.

Chain Belt Co. has announced the appointment of **George H. Woodland** to the newly created position of General Sales manager, industrial divisions. Mr. Woodland has been with Chain Belt since 1938.

Robert Harcus, executive vice president of Byron Jackson Co., has been appointed to the Membership Advisory Council of the Atomic Industrial Forum.

S. L. Crawshaw, nationally known gearing industry executive, has been appointed to the position of assistant to the president of the Philadelphia Gear Works, Inc. Mr. Crawshaw brings to Philadelphia Gear thirty years of technical and executive experience in the gear-making industry.

Stanley Engineering Co., consulting engineers, has advanced **Roy F. Vanek** to the position of associate. In his new position, Mr. Vanek will continue his responsibilities in connection with power projects throughout the Middle West. He will also assist the partners in administering the activities of the company.

James D. Baker has been appointed director of engineering of Copes-Vulcan Division, Continental Foundry & Machine Co. Research and engineering have been consolidated under Mr. Baker, whose responsibility it will be to extend the development of the product line to cover complete equipment for boiler installations.

A. A. Markson, formerly head of mechanical research and development, has been named assistant vice president in charge of engineering for Hagan Corporation. In his new position, Mr. Markson will assist R. R. Donaldson, company vice president in charge of engineering, in the coordination of all engineering activities in Hagan's mechanical division.

Bailey Meter Company has announced several changes in top management. **Paul S. Dickey,** former vice president and a director of the company, has been elected president succeeding **Robert S. Coffin,** who was elected chairman of the executive committee and named management consultant. Coffin, with the company since its establishment in 1916, had been president since 1944. **Harvard H. Gorrie,** chief engineer, has been elected a vice president in charge of all engineering activities, and

Raymond D. Junkins, head of the patent department, has been elected a vice president and director.

Dr. Moyer D. Thomas of Stanford Research Institute is the first recipient of the Frank A. Chambers Award presented by the Air Pollution Control Association. The presentation was made to Dr. Thomas principally for his development of the Thomas Autometer, a recording instrument for the analysis and measurement of sulfur dioxide in the air.

Eric A. Kerbey was elected president of Midwest Piping Co., Inc. at a recent directors' meeting. Kerbey has been with themsince 1928when he established the Chicago sales office.

Frank F. Elliott, senior vice president of sales for Crane Co., has been elected president and chief executive officer of the company succeeding John L. Holloway, who resigned as president and director because of ill health.

At a recent meeting of the board of directors of The Allen-Sherman-Hoff Co. **B. C. Berry** was elected chairman of the board and **H. E. Allen** was elected president.

William C. Denison was elected to the board of directors of American Brake Shoe Co. Mr. Denison is president of the Denison Engineering Co. which was recently purchased by American Brake Shoe Co.

John Rowland Brown, president and general manager of Reliance Gauge Column Co. was awarded the grade of Fellow in The American Society of Mechanical Engineers at a recent banquet of the Cleveland section. Mr. Brown has been a member of the Society for 55 years.

Allison C. Neff, vice president of Armco Drainage & Metal Products, Inc., was named the new president of the National Society of Professional Engineers at the annual banquet of the group held recently.

Frederick W. Utz has been elected president and a director of the Safe Harbor Water Power Corporation, owner and operator of a 230,000-kw hydro-electric development on the Susquehanna river at Safe Harbor, Pa. Associated with Stone & Webster Service Corp. since 1946, Mr. Utz will continue as a vice president of that company.

The ASME George Westinghouse Gold Medal Award was given to **Rear Admiral Hyman George Rickover,** chief of the Naval Reactors Branch, AEC Division of Reactor Development, and director of Nuclear Power Division, Navy Bureau of Ships.

Business Notes

Albert F. Sperry, president of **Panellit, Inc.,** has announced the formation of a Canadian affiliate, Panellit of Canada, Ltd. The new organization will specialize in engineering, design and fabrication of industrial automatic control systems, graphic and control instrument panels and information systems. T. A. Hislop, who was formerly associated with Canadian Industries, Ltd., is chief engineer of the new facility.

The **C. J. Gaskell Co., Inc.,** of Memphis, Tenn., has been named sales representative for Western Tennessee, Southwestern Kentucky, Northern Mississippi, Northeastern Arkansas and Southeastern Missouri by **J. F. Pritchard and Co.** of California, Kansas City and Missouri.

As of April 1 the name of the **British Electricity Authority,** England, was changed to **Central Electricity Authority.**

The world's first industry-owned, nuclear materials test reactor will be built by **Westinghouse Electric Corp.** at a cost of six and one-half million dollars. This sum represents the largest commitment of private funds for an atomic power development

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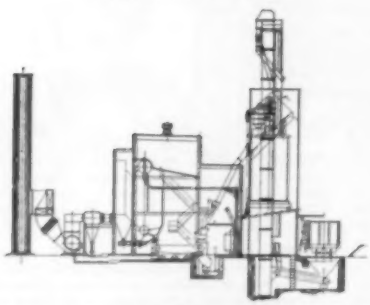

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FIG. 29 Cylinder with Impeller

FIG. 17-28 Cylinder

FIG. 215 Flanged

FIG. E-57 Double Window

FIG. 212 Visibility Welding Neck or Screw

FIG. E-811 Flapper

FIG. E-1810 Rotating Wheel Type

All sizes up to 6" *Send for Catalog*

ERNST WATER COLUMN & GAGE CO.

LIVINGSTON, N. J.

facility ever made by American industry.

Shareholders at the annual meeting of **American Locomotive Co.** recently approved a change in the name of the 118 year-old concern to **Alco Products, Inc.** The new name has been adopted to reflect the company's increasingly diversified operations which have grown beyond its role as a leading locomotive supplier.

Sauerman Bros., Inc. have moved their general offices to 620 S. 28th Ave., Bellwood, Ill. The new office building is adjacent to their Bellwood plant and provides enlarged facilities for all departments.

A new type of vacuum pump invented by a University of Wisconsin physicist, Prof. R. H. Herb, and patented by the **Wisconsin Alumni Research Foundation** will soon be released for sale. The new, completely dry, high-vacuum pump will be made and marketed by **Consolidated Vacuum Corp.**

A contract recently signed for the installation of a 200,000-kw steam electric generating unit, the largest single unit ever built for the company, will help **Niagara Mohawk Power Corp.** provide a total of 3,100,000 kw with which to supply the expanding industrial and agricultural area Niagara Mohawk serves. Completion of the new unit is scheduled for the fall of 1957.

Crusher Engineering, a new division of **Poor & Co.,** with headquarters in Philadelphia, has been announced by the company in Chicago. The new division, will make available a complete line of jaw and roll crushers, hammermills, impact breakers, Bradford breakers and pulverizers to industrial markets.

The **General Electric Co.** has received an order from the **Consolidated Edison Co.** of New York for a 300,000-kw steam turbine-generator. The unit will be the largest yet manufactured by the company.

Frederick W. Richmond, New York industrialist, and Henry E. Haller, Sr., president of **National Valve and Manufacturing Co.** of Pittsburgh, jointly announced recently the sale of the power and industrial piping firm to Mr. Richmond and a group of investors. The purchase price was between $4\frac{1}{2}$ and 5 million dollars.

American Radiator & Standard Sanitary Corp. has established a new division to coordinate all of the corporation's activities in the atomic energy field, commencing with the development of complete reactor systems and components. Frank A. Parker has been appointed director of the new division, and David J. Mallon has been named director of research operations. Headquarters of the division will be in Redwood City, Calif.

North American Aviation, Inc., strengthened its organization in the commercial field of atomic energy by establishing a separate nuclear engineering & manufacturing division and electing Dr. Chauncey Starr as vice president in charge.

U. S. and foreign engineers, scientists and industrial representatives from 24 business and technical societies, 16 universities, 13 government bureaus and AEC contractors, and 34 major U. S. industrial corporations will present nearly 300 papers in 50 sessions in one week covering practically every phase of peacetime uses of atomic energy and its by-products at the **Nuclear Engineering and Science Congress** in Cleveland December 12 through 16.

Stone & Webster Engineering Corp. has been named as engineer constructors for the first Army package power reactor. This small power plant will employ components which can be transported by air to remote bases in any part of the world. A small charge of fuel will operate the plant at its full capacity for a period of 18 months.

Assure constant material flow from your bins and hoppers with . . .

DEPENDABLE SAFE ECONOMICAL QUIET

PneuBin Pulsating Panels

PneuBin is a new concept in material flow engineering. The PneuBin unit consists of steel-backed, neoprene, pulsating panels, strategically located on the inside walls of your present bins. Working off the plant's regular air supply, PneuBin is inflated and deflated in controlled cycles, causing the contents of the bin to be "positively displaced" and thus assures free flow of material through the discharge opening.

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SAFE—No manpower is needed to facilitate material flow from bins when PneuBin is on the job. No more prodding, poling or sledge-hammering. *Depend on PneuBin to insure material flow . . . safely.*

ECONOMICAL—PneuBin cuts maintenance costs, saves money year after year. Reduce bin damage . . . increase bin life. *Depend on PneuBin to insure material flow . . . safely, economically.*

QUIET—PneuBin pulsating panels breathe . . . not snore. No hammering or loud vibration noises. PneuBin's quiet operation adds to overall plant efficiency . . . reduces employee fatigue. *Depend on PneuBin to insure material flow . . . safely, economically, quietly.*

Send for "Flow Stoppage" and free literature. PneuBin engineers will gladly make recommendations with no obligation on your part.

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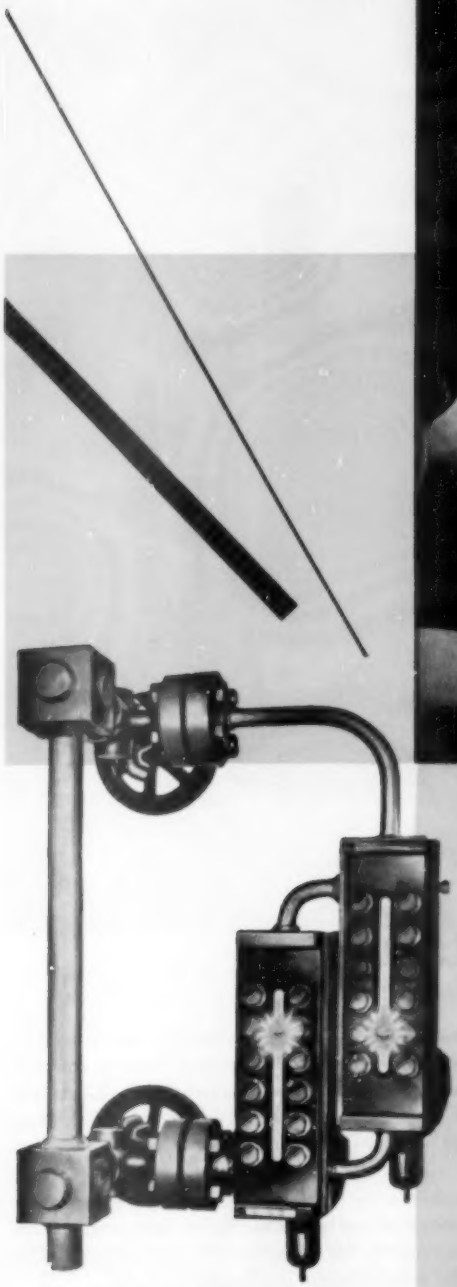

Yarway High Pressure Boiler Water Gage with separated-design flat glass inserts. Write for Yarway Bulletin WG-1812

HE'S A SPECIALIST ON STAINLESS STEEL INLAYS

● A dentist? No.

He's a Yarway craftsman. In the picture above he is milling a gasket groove in the stainless steel facing that is used for this important part of a high pressure boiler water gage body.

The man is important; so is the inlay.

The man is typical of the skilled workmanship that goes into every Yarway gage, blow-off valve, steam trap or other product —workmanship that makes no compromise with quality.

The stainless steel facing is typical of advanced Yarway engineering design. That inlay is but one of twelve basic improvements made in Yarway high pressure water gages.

When buying boiler water gages as well as other steam plant equipment, measure the cost in terms of good engineering, quality, workmanship, and dependable service.

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BLOW-OFF VALVES
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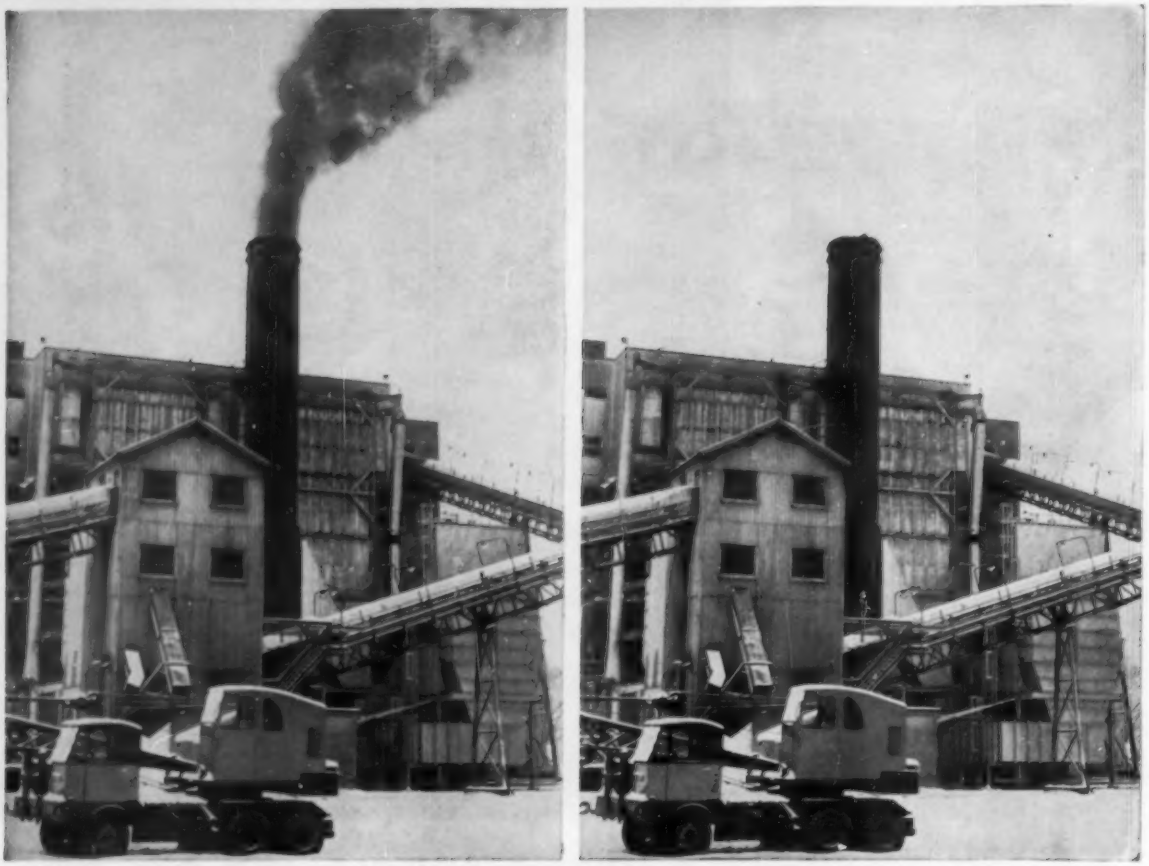

Fly Ash Problem Solved By Central Station

This Pennsylvania utility felt that as long as you can *see* dirty stack discharge, you have a problem. To solve it, they decided to insist on fly ash collection equipment with very high efficiency.

The electrical precipitators they chose, which were placed after existing mechanical collectors, are Cottrells, designed and built by Research-Cottrell. Their effectiveness is demonstrated in the above unretouched photographs. At the left, the precipitators were turned off long enough to take the picture showing the volume of fly ash discharged by the boilers. At the right, the precipitators are turned back on. Stack discharge is visually clean.

This is another example of industry's trend toward establishing its own higher standards for nuisance abatement. Research-Cottrell, which has made more fly ash installations than any other company, cites the following comparison:

In the period from 1923 to 1939 only 11% of its power plant customers specified fly ash collection efficiency of 95 to 98%. In recent years, that 11% has risen to fully 90%.

One reason, of course, is the generally increasing emphasis on community relations. Another factor is that far-sighted companies are anticipating stricter smoke regulations. They are anxious to install equipment that will end their smoke problems now and also prevent such problems from occurring in the future.

Still another factor is this. In recent years, with modern coal pulverization and advanced boiler design, there has been an increase in the fineness of fly ash particles. This calls for the most efficient equipment available.

Read—in Bulletins FA and MI—about Cottrell equipment and the Research-Cottrell's MI Rapper. This device eliminates rapping puffs and enables the precipitator to maintain, continuously, its high collection efficiency. Write for your copies today.

RC-183

RESEARCH-COTTRELL, INC.

A WHOLLY OWNED SUBSIDIARY OF RESEARCH CORPORATION

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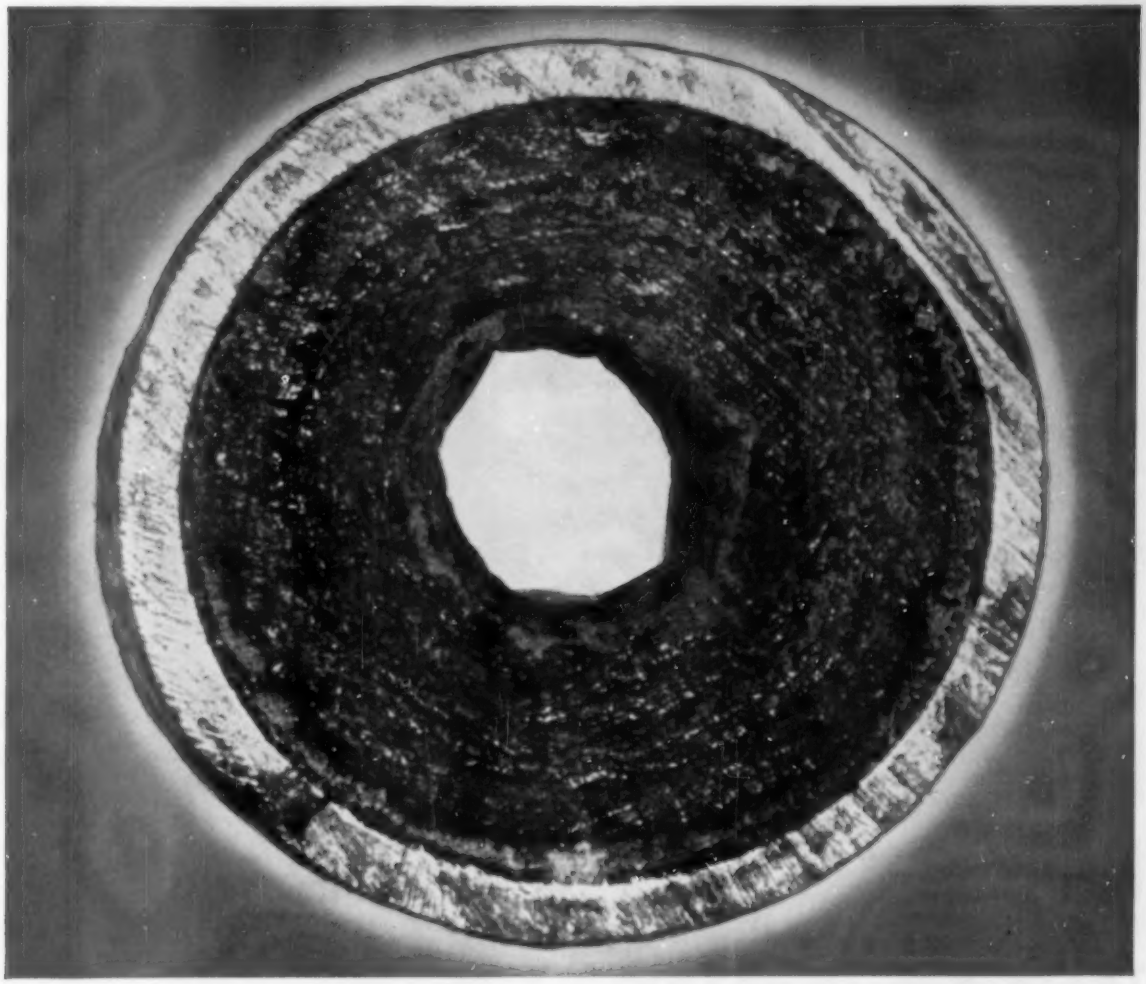

END OF THE LINE

SCALE—layer upon layer of it—has reduced the inside diameter of this pipe to practically nothing. It's a common occurrence in some power plants, and the results are costly. The line must be taken out of service. That means production loss and expensive maintenance or replacement.

Scale, sludge, carry-over, and return-line corrosion are but a few of the problems that must be overcome to assure efficiency in boiler plant operation. In Dearborn's complete line of water conditioning products, there is the correct treatment to eliminate every water trouble—the properly balanced treatment to reduce unnecessary maintenance, avoid shutdowns, and protect valuable equipment.

Since 1887, Dearborn products have provided trouble-free water to users of steam in all types of industry. That's why, today, power engineers in leading industrial plants throughout the nation look to Dearborn for consultation and assistance in solving their water treating problems.

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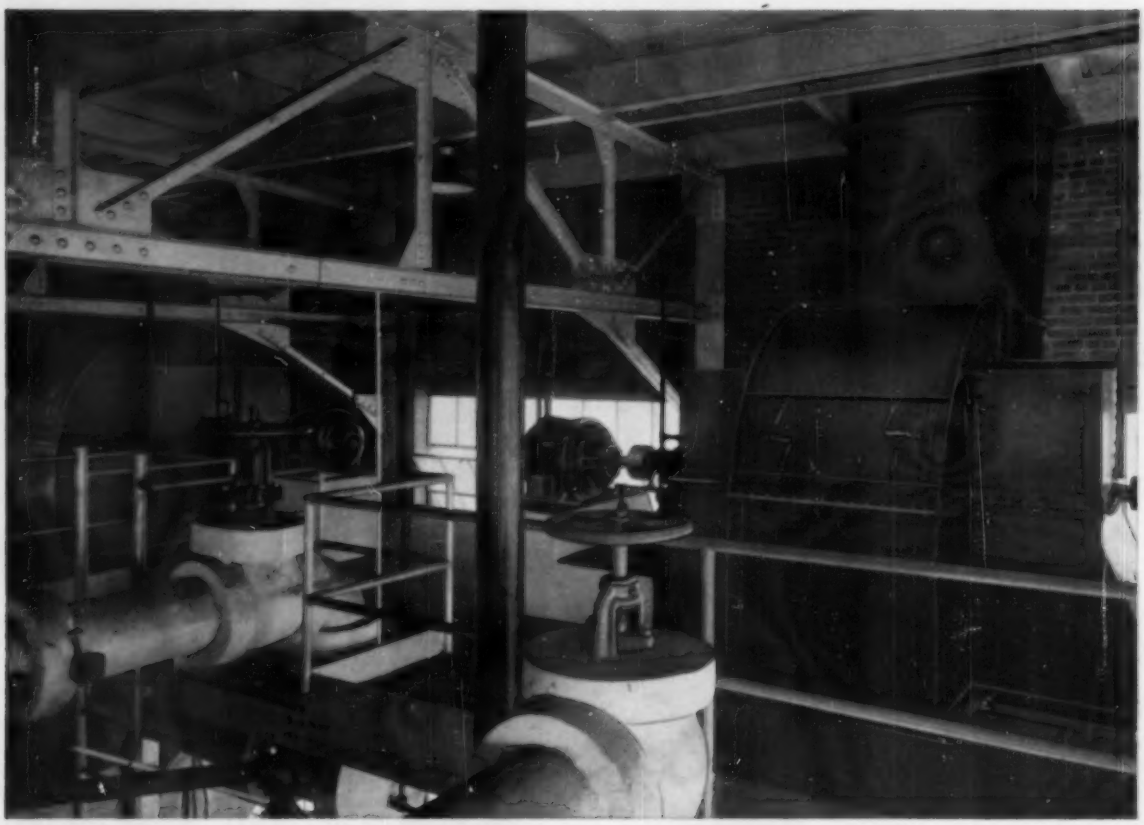

EVERY TON OF FUEL YOU BURN TAKES 12 TONS OF AIR

See P. 545 of FAN ENGINEERING, 5th Edition, chapter on Combustion and Mechanical Draft.

Since approximately twelve pounds of air must pass through your boilers to burn a pound of combustible, your draft department is no place to cut corners. Also, today's high pressure requirements for super-heated steam, plus air preheaters and flue gas cleaning equipment in the system, place extremely heavy loads on the fans. It calls for the best fans you can get!

This is why so many power plant operators use "Buffalo" Forced Draft, Induced Draft, Gas Recirculating, Primary Air Fans and Overfire Blowers. They're built with one thought: to deliver the draft your fuel requires, with the lowest possible maintenance costs, and the shortest and fewest possible draft timeouts. Have us mail you Bulletin 3750 and see why your best choice is "Buffalo".

**The "Q" Factor — the built-in Quality which provides trouble-free satisfaction and long life.*

SPECIFY "Buffalo" THE DRAFT FANS with the "Q" Factors

- Built to stand up
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- Performance characteristics to meet pressure demands in modern steam generation practice

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And where do vacations come from? They come from brick! Yes, refractory brick.

The brick that lines the furnaces of industry . . . contains their heat . . . produces the steel for that hook on the end of your line and the glass rod that holds it. Your waders, too.

Behind everything that's made lies refractory brick.

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These are what General Refractories contribute to your happiness, your welfare, your daily life. Everywhere. Swiftly. Dependably. Economically.

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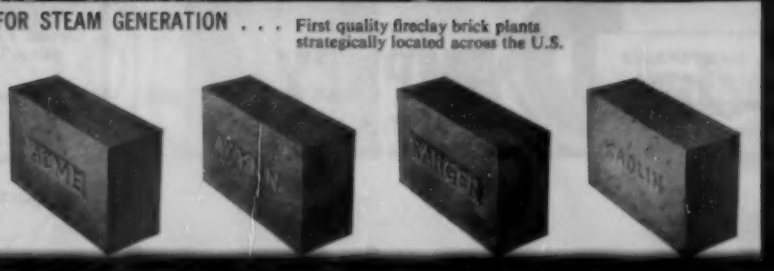
FOR STEAM GENERATION . . . First quality fireclay brick plants strategically located across the U.S.



FOR WANT OF A NAIL...

Something that wasn't there once cost a king his life.

For today's boiler, lack of internal protective surfacing is hardly a life or death matter. Yet consulting engineers . . . insurance underwriters . . . power plant operators increasingly specify, recommend, and purchase Apexior Number 1 for tube and drum coating. Why?

Because the yardstick of return on investment proves Apexior's unique service *now pays off at the highest rate ever* . . . for modern boiler design and operation today permit a single Apexior application to deliver maximum protection not only for a normally anticipated five years, but for one — three — sometimes even *five years more!*

And because Apexiorizing is now a one-coat procedure, former material and labor estimates are halved. Protection that can last twice as long today costs *half as much* . . . a trifling pennies-per-square-foot premium to insure full return on a major capital investment.

Like the legendary nail, boiler protective coating may seem a factor of small significance — yet it can mean the difference between acceptable performance and the best of which the modern boiler is capable. The assurance every inspection gives that tubes and drums are functioning at new-metal peak efficiency is the measure of Apexior's service in maintaining highest steam production reliability and quality — a contribution measured ultimately in profit dollars.

Internal boiler protection is but one phase of Dampney corrosion-control activity. Dampney Coating Systems for specified end-use service protect cooling towers — intake water structures — pipeline interiors. For a recommendation to meet your requirements, write

MAINTENANCE FOR METAL

THE DAMPNEY COMPANY

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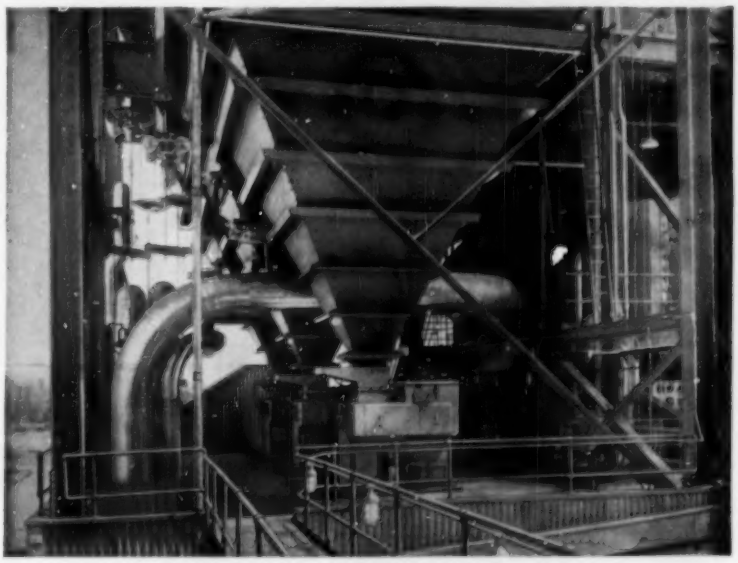
Carolina Power & Light

again specifies

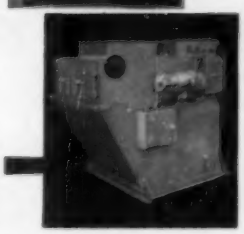
Richardson

Richardson Automatic Coal Scales are playing a vital part in helping supply power for the new Industrial South. Here are Richardson Model 39's in an outdoor installation at the new generating station of Carolina Power and Light.



To both industrial and utility power generating stations, specifying Richardson means—

1. A 24" x 24" inlet opening and 26" wide belt for maximum coal flowability.
2. All wiring and controls outside coal chamber.
3. Access doors which will not spill dust on floor when opened.
4. Beam ratio test facilities outside coal chamber.
5. Gravity operated by-pass, with no restriction of coal flow to downspout.
6. No drag links or wires attached to weigh hopper.
7. Nationwide after-delivery service.



Latest development in the 39 Series of Richardson Automatic Coal Scales is the Model H-39 shown below. May we send you our new 16-page engineering data book on the H-39 Coal Scale (Bulletin 0352), without cost or obligation?

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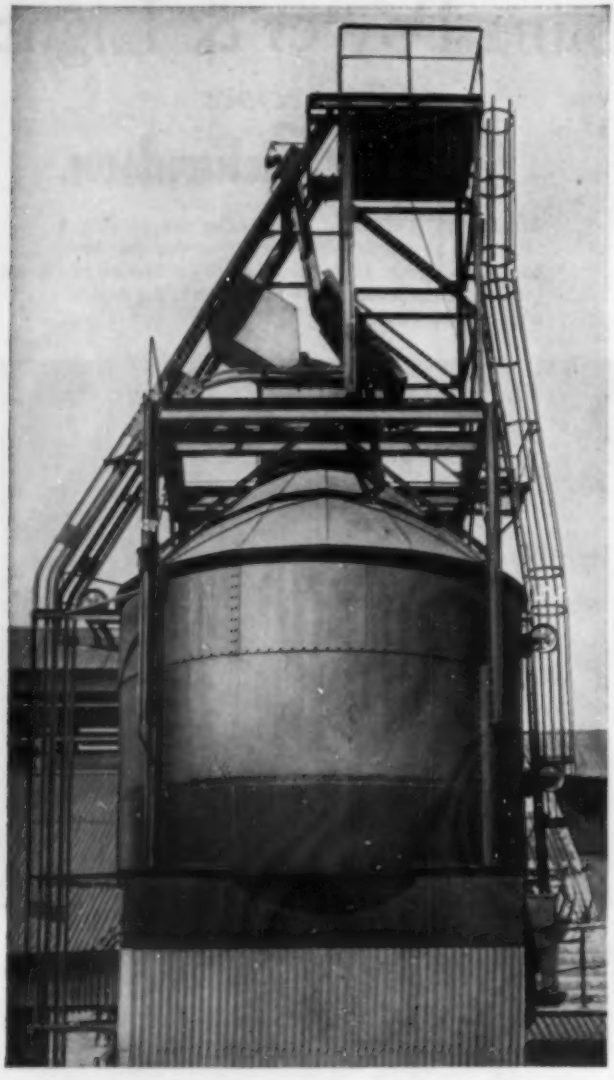
MATERIALS HANDLING BY WEIGHT SINCE 1901



LOW COST DEPENDABLE COAL HANDLING FOR PUBLIC UTILITIES

Salem Gas and Light Company, Salem, Mass., found a G-W Skip Hoist the ideal solution to the problem of conveying coal and coke to producer storage. The skip bucket keeps the producer-storage bin filled at all times . . . and does the job with maximum economy.

Gifford-Wood Skip Hoists . . . one of many G-W systems of materials handling . . . are low in initial cost . . . low in maintenance . . . long-lived . . . completely dependable. Public utility companies the country over are becoming increasingly interested in Skip Hoist handling of coke, coal and ashes where space is limited and both initial and operating costs must be kept at rock bottom.

This particular installation may not be the perfect solution to your own particular problem. Gifford-Wood, however, has specialized in the design, engineering and installation of all types of materials handling systems for 136 years. To have a Gifford-Wood Materials Handling Engineer survey your present method of moving materials, places you under no obligation and it may well be your first step toward lower operating costs and increased production.

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Diamond Service Engineer instructs operator in use of the Diamond Selectromatic Control Panel . . . how simple it is to change from single blower selection to a completely automatic sequential program.

The severe punishment that boiler cleaning equipment must take in the normal course of its operation emphasizes the importance of the unique Diamond Service Policy. Throughout the 36 years it has been in force, this Diamond Service Policy has made significant savings and important improvements in boiler cleaning for many users of Diamond Blowers.

Every installation of Diamond Blowers in stationary water tube boilers is regularly inspected and adjusted *(unsolicited and without charge)* by one of the many full-time Diamond Field Service Engineers working from strategic points throughout the country. On an inspection call, the Diamond Service Engineer sees to it that the blowers are in good repair and adjustment . . . instructs operators in their correct use and care . . . recommends blowing schedules for maximum economy. Often he will detect potential trouble before it becomes serious or costly. This preventive maintenance has been of great value to many operators.

Numerous users tell us that this unique Diamond Service Policy was as important as the superior design of Diamond Blowers in their decision to buy Diamond equipment.

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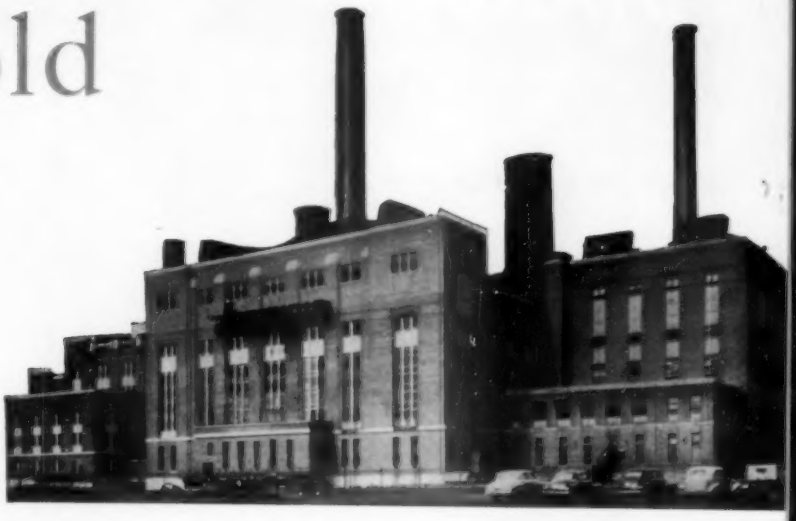
Pioneering: an old story to Shaw



Philip Sporn, president of the American Gas and Electric Company, whose planning, leadership and vision have made the history-making project at Philo a reality.

History is in the making at the Philo Plant of the Ohio Power Company . . . where a pioneering project of tremendous importance is under way. Now under construction at Philo—one of the major plants of the American Gas and Electric Company System—is Unit 6, the first commercial steam electric generating installation to utilize steam *above* the critical pressure of 3,206 pounds per square inch. The world's most efficient unit, its steam generator will deliver steam at 4,500 p.s.i. pressure and 1,150° F. temperature to the turbine. The turbine will be the first to use steam reheated twice during its passage through the unit. Because of Shaw's world-wide reputation for careful planning, diversified experience, skillful fabrication and dependable, economical installation, they were chosen to fabricate and install the piping for this pioneering project. Pioneering is an old story to Shaw, for as far back as 1929, in a plant built by American Gas and Electric Company at Deepwater, New Jersey, Shaw fabricated and installed piping designed for 1,500 p.s.i. pressure—as history-making then as 4,500 p.s.i. is today. However challenging *your* piping problem, you can depend on Shaw for the right answer.

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